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The magazine *for*, *by*, and *about* telescope makers!

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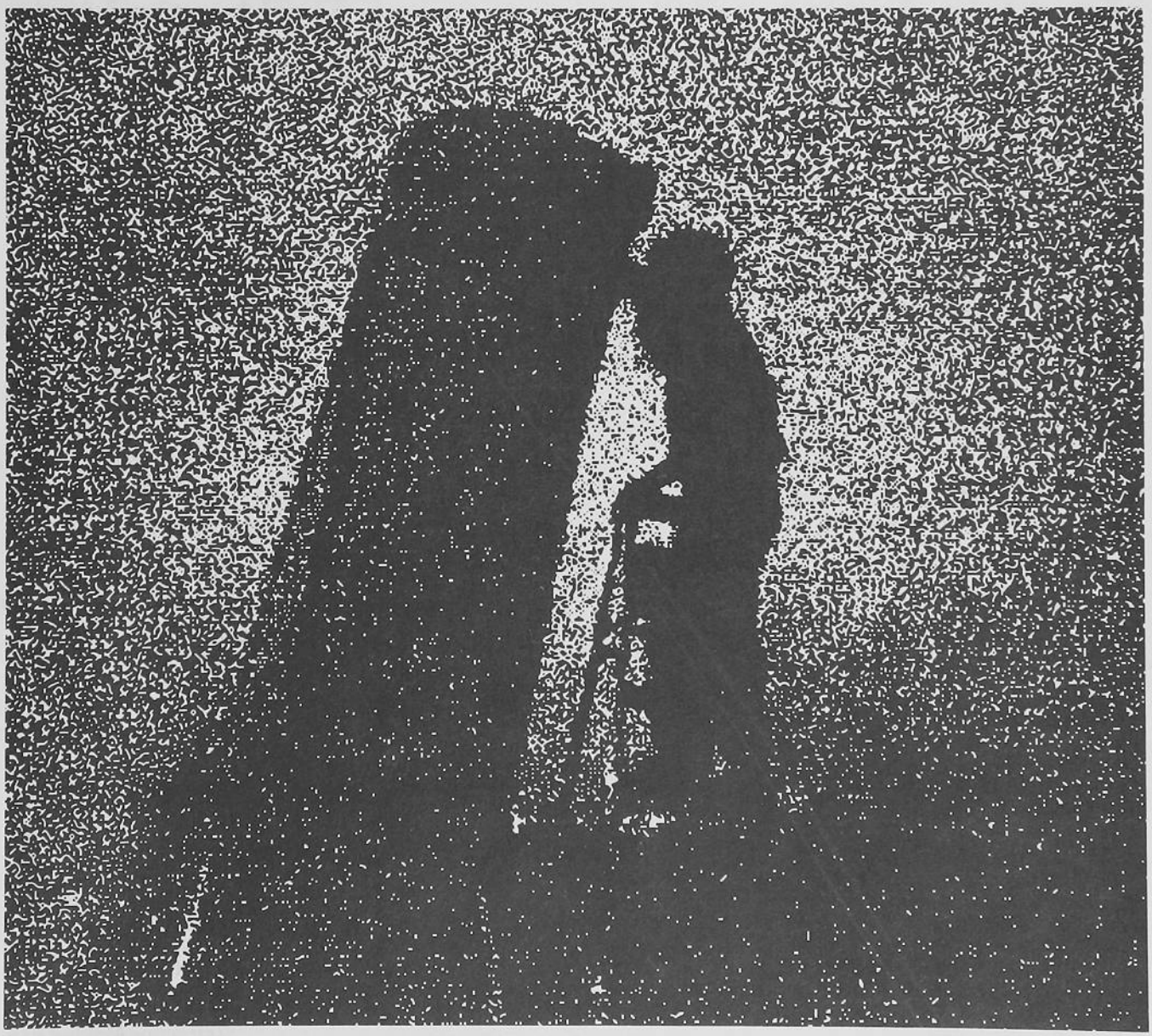

Telescope Making #36

The magazine *for*, *by*, and *about* telescope makers!

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Cover: Stargazing at the Winter Star Party. The photo was taken by a very helpful photographer, whom I met in the dark and whose name I didn't write down. The photo was scanned at 75 dots per inch in line-art mode, saved in Macpaint format, edited in Superpaint, and printed as part of a Ready,Set,Go! document TM#36/Cover.

Editorial

The first day of Spring and the last day of *Telescope Making*'s prepress preparation arrived in the midst of a snowstorm. As I watched the big, soft flakes drift by outside the window, I remembered the warm nights of perfect seeing at the Winter Star Party. Ahh, what a fine lesson in doing astronomy!

But the real lesson I learned under those steady Florida skies is that big Newtonian reflectors are capable of diffraction-limited performance. In the decade since the Dob was "discovered" we have seen few that give truly fine images. We have, as a community, variously blamed seeing, fast focal ratios, tube currents, collimation,and poor eyepieces for the soft star images that we all too often tolerated.

All these *are* problems common in large Newtonians. But there is another problem: poor optics. It's an insidious problem because not easy to wait a year or more for a mirror, install it in a telescope, and– *voilà*– a wave of spherical aberration before your eyes!

Send it back? Reject it? No!–I can't part with it. Wait a few nights? Maybe it'll get better by itself!

But that fuzziness stays and stays, until it seems like part of the telescope. With a bit of off-axis masking, a newly acquired aversion to the planets, the telescope maker compensates, by specializing in observing nothing but faint fuzzies.

That's not what should be happening. Florida's skies proved to me that quality optics make big scopes really sing. Sure, the seeing where you live isn't as good as Florida's seeing—but it's not *always* bad, is it? But bad mirrors are *always* bad.

If you can't bring yourself to be objective, bring in some friends and let them be tough for you. And for goodness sake, if a mirror can't pass muster, tell people about it. Let 'em know where you bought it. It's time telescope makers got together, got tough, and got good mirrors for their money. Enough said.

— — —

Don Scott's epoxy-paper construction techniques have applications well beyond the "Master Plumber" focuser. Andrew Sorenson's long refractor should encourage those who have rejected building a refractor on the grounds that lenses are too difficult to make. Whether your plans are as ambitious as Nick Nichols' plans, or you want just to expand a tight space with a little more storage as Bob Reeves did, you'll find ideas that you can use for your own projects.

— — —

Finally, those who wrote to *Telescope Making* to express concern for or make contributions to John Dobson should contact Don Stone, Treasurer, East Bay Astronomical Association, 731 Camino Ricardo, Moraga, CA 94556. The East Bay group is willing to act as a conduit for money donated to John.

I'll be at the Riverside Telescope Makers Conference this year—hope to see you there.

—Richard Berry

Letters

Test On Receipt

Dear Mr. Berry/ I read John Brooks letter in *TM#35* with great interest. I recently bought a new "1/20 wave" custom 8-inch f/9 mirror only to find that it has a broad turned-down edge. Although I'm sure its very reputable maker will correct its defect, I agree with Mr. Brooks on the need for testing commercial optics no matter how reputable their source.

However, I differ with him on method and intent. If a mirror is no good, I just send it back. I feel no need to quantify the errors.

I've almost always had a telescope nearly ready for its optical parts when they arrive. I put them into the telescope and test them by the Ronchi star test. Usually I know at a glance whether I have a jewel or just another turkey to send back to the farm.

Unfortunately, Mr. Brooks' Zygo Mark IV is far removed from the multitude who are trying to use expensive shaving mirrors as telescopes. So too, is the knowledge that an idiot-proof, cheap, elegant test is available in the form of a simple Ronchi eyepiece costing less than $5 to make.

For those who don't have access to a Zygo Mark IV, a good Ronchi screen of 133 lines per inch is available from Willmann-Bell Inc., Box 35025, Richmond, VA 23235, for $2.50 plus a $1 handling charge.

Because there is no need to quantify significant error to reject a commercial optic, but only a means to recognize it is necessary, why shouldn't we "optical morons" be able to make our own good mirrors -- not 1/50 wave masterpieces -- by idiot-proof testing methods? What's wrong with using the Ronchi star test in the telescope until the paraboloidal null is reached?

The very easiness and simplicity of Ronchi testing, if promoted for beginners, could free telescope makers who are now the hostages of commercial vendors who make a good mirror only when they have to, or are incapable of making a good one at all.

If the master optician who made me an 8-inch f/9 with a turned edge had checked it with a $2 Ronchi screen at the focus, I'd still be buying. But he converted me. From now on, I'm grinding my own.

Don Scott
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MIRROR 2.0 Available

Dear Richard/ I am preparing a new version of program MIRROR. It now supports coprocessors, Hercules graphics, and has enhanced operation. *TM* readers who are interested can contact me directly.

Many people might be confused about how many mirror analysis programs I have written and think that they are using the only one. I have, to date, written about two-and-a-half programs.

My flagship program, MIRROR 1.0, is a long, graphics-oriented program that does a combined Millies-Lacroix and Texereau method reduction. It does the variation of minimizing wavefront error directly. MIRROR also allows my method of exploratory focus to be used. It was MIRROR 1.0 that Mr. Dobson was apparently using at Alcon 88, pictured in *TM#35*.

The new release is MIRROR 2.0.

In addition, I have written the generic exploratory focus program GENMIR.BAS, which appeared in my article in *TM#32*. GENMIR is not graphics-oriented but is portable between different brands of computers. Unfortunately, some BASIC interpreters output more digits than others, so output can be messy. I include an improved version of this in my new distribution diskette.

Finally, I've done a modification of the program in Texereau. This program is not graphics oriented and was written to be generic as far as possible.

Dick Suiter
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Panama City FL 32405

ABCs of Diagonal Testing

Dear Richard/ We all share John Brook's outrage (see *TM#35* Letters), but we also must realize that expecting superior quality optics at current prices is rather unrealistic. Anyone who has made even one mirror knows that making 1/20th-wave optics and selling them at current prices is incompatible with life. Those who insist on purchasing quality optics should order from professional companies (i.e., Melles Griot, Carl Zeiss, etc). The products you get this way will have the quality you want, with a price to match it.

Those with more modest budgets should learn more about making, or at least *fixing*, their own optics. Instead of a good flat that you recommend to John for testing diagonal mirrors, he and others in his predicament can use the simple A-B-C method described in *Amateur Telescope Making Book One*, page 55. Order *un*aluminized diagonals, test them with the ABC method, return the bad, and fix the better ones.

However, John is right -- a good quality diagonal is not too much to ask for. These mirrors hardly exceed 3 to 4 inches in diameter on amateur telescopes, and a 1/10th-wave surface of that size is really not an unreasonable expectation.

Continued on page 36...

The Comparative Costs of Telescope Mirrors

There's an old rule for determining the cost of the "standard" equatorially mounted reflector: that the total cost increases with the square of aperture (or perhaps with the cube of aperture in large sizes).

While this is probably still true of equatorially mounted reflectors, since the Dobsonian revolution the "standard" reflector's ball bearings and counterweights have given way to Teflon and plywood. Without the optics, the cost differential between a 10-inch and a 12.5-inch Dobsonian is typical well under $50 for instruments with similar focal ratios.

Thus the cost of the optics has perhaps become the primary factor in the total outlay for most homebuilt visual reflectors because most TMs now purchase their optics, and most choose to mount them in inexpensive Dobsonian telescopes.

For those builders with limited resources but with simple carpentry skills, the heavens lie open to the eye as never before. Because there are few commercial sources of big, thin mirrors at low prices (at the penalty of long delivery times and comatic focal ratios), most smaller Dobsonian projects seem to be built around "full thickness" mirrors with slower focal ratios than the big f/4.5 "light buckets." And, as past letters to the editor will confirm, TM subscribers are not wealthy engineers whose projects are limited only by the calculated mass. So for the enlightenment of poor beginners wanting reasonably large telescopes, I made a study of aperture versus cost among commercial optics using the "photon per dollar approach."

I compared five well-known sources of commercial optics for price on 6-inch to 14.5-inch mirrors with standard aluminizing, and the prices were converted to dollars per square inch for each aperture. Table 1 shows the actual cost per square inch from manufacturer A through manufacturer E. The average cost is listed in the last column. Prices are those a buyer would pay including shipping, and not the list price.

It is interesting to note that the average cost per square inch of mirror surface drops when going from the 6-inch to the 8-inch, and drops again in the move upward from the 10-inch to the 12.5-inch mirror. This drop in price per square inch is the rule for most of the manufacturers of 8-inch and 12.5-inch mirrors.

Table 2 compares the gain in area to the gain in average price relative to the next smaller standard size. This represents the incremental cost of "buying up" to the next largest size; that is, how much more it would cost you to buy a 10-inch if you were already considering an 8-inch. The 6-inch mirror is compared to the 4.25-inch, which is not listed. Here is where one increase in aperture can be seen as an obvious bargain, and another as perhaps a dubious move, at least economically.

The bargain of the study is the 12.5-inch mirror. For an average price increase of 50 percent, there is an area gain of 36 percent over the 10-inch mirror. Contrast this to the 14.25-inch-aperture optic strongly touted when it was introduced a few years ago. It offers only a 26 percent area increase over the 12.5-inch for a whopping 122 percent cost increase. Here increasing aperture absorbs dollars much faster than it gathers photons, at least with standard thickness optics.

In smaller sizes, an 8-inch over a 6-inch is as sound a move economically as it is optically — something for those making a first telescope to consider. For a 44 percent increase in light, you pay a 67 percent increase in price. That's quite reasonable. Like the 12.5-inch, the 8-inch mirror usually costs less per square inch than the size smaller, and in one case, less than another make of 6-inch mirror.

Of course there are other considerations in determining the aperture of a first or next project — such as the absolute mass the average astronomer (or even an engineer) can move, and the absolute mass of dollars he or she can afford part with. There's also the "I don't care how big a bargain the mirror is, where will we keep a 12.5-inch telescope?" problem. If you can't store the telescope anywhere, you might as well not have it.

Of course, as a nutty TM, you'd have to reply: "Maybe we could keep it in the parlor? I could paint it black, get some stovepipe and disguise it as a big wood stove."

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Table 1
Commercial Mirrors
Cost per square inch (in dollars)

	A	B	C	D	E	Avg.
6.0"	6.74	----	3.51	3.72	4.96	4.73
8.0"	5.28	----	3.17	5.02	4.38	4.46
10.0"	6.05	4.14	4.46	4.92	5.22	4.96
12.5"	6.11	3.87	4.07	4.45	5.22	4.74
14.5	8.79	5.61	9.09	----	----	7.83

A - Telescopics
B - Galaxy Optics
C - Parks Optical
D - Edmund Scientific
E - Meade Instruments (Retailer: Adorama)

Table 2
Percent Increase in Area and Average Price
(over next smaller aperture)

	Area (in^2)	Price (Avg.)	Area Gain	Price Gain
6.0"	28.2	$134	49	---
8.0"	50.2	$224	44	67
10.0"	78.5	$389	36	74
12.5"	122.7	$582	36	50
14.5"	165.0	$1,292	26	122

Building the "Master Plumber" Focuser with Epoxy-Paper Construction

The hardware store, even the modern blister-pak version, is as much the parts repository for the poor man's telescope as it was in Russell Porter's day. Materials and techniques have changed, to be sure, but the spirit remains the same.

Though serendipity is rare when plumbing goes haywire, I found that a plastic "Master Plumber" flush valve (about $5.95 at True Value stores) can be converted into an excellent 2-inch focuser. If you already have certain basic telescope-maker's tools, such as slow-curing epoxy glue and a few small drills and taps, the total cost of a 2-inch ultrashort focuser including a 1.25-inch adaptor can be kept around $10.

The "Master Plumber" valve has a clear bore slightly over 2 inches, and an epoxied-in kraft-paper sleeve will reduce it to fit 2-inch eyepieces perfectly. The valve has twelve parallel threads per inch on the outside and comes with a ribbed plastic hex nut that you can easily convert into the focuser's base.

The Focus Assembly

Strip the rubber gasket from the assembly. Using the flange of the valve as a guide, cut off the threaded barrel with a hacksaw. Turn the piece frequently; don't just cut straight through it. If you cut with care, the cut end will come out square and will need only chamfering and dressing against a piece of sandpaper on a flat surface.

At the cut end there is a small inner ring that may not be concentric with the rest of the bore. If it's

not, file or sand off the slight protrusion. Lightly sand the entire bore, just enough to cut the gloss. Also degloss the outer unthreaded lip.

The nut is tapered on its outside flats and is larger on the open side. On a piece of 1/8-inch five-ply model aircraft birch plywood (6 inch by 12 inch is the smallest available in hobby stores),trace around the larger side of the nut. Then screw the barrel in and trace around the inside of it. Remove and invert the assembly, unscrew the nut,and trace around the outside of the barrel after aligning its inside wall with the previous line. The final circle, cut out with a coping saw or sabre saw with a scroll base, will leave a central hole that should be sufficient to clear the barrel through the base. But check it.

Cut out the plywood plate and dress its outside edges with sandpaper as the barrel was, until it matches the outside edges of the nut exactly. The nut is made of a slick plastic to which few adhesives will stick. Drill through each partition with about a 3/32-inch drill, place the nut on a leveled surface, mix a batch of epoxy, and fill the open side of the nut with it. The holes will keep the epoxy reinforcement attached to the nut.

From a 60-pound (heavy-duty) kraft paper grocery sack, cut a piece of paper slightly smaller than the barrel-height wide and about 7 inches long. Curl the paper by stroking it over a scissors edge and trim the length so that the edges butt around the inside of the barrel. Cut two or three strips exactly 3/8 inches wide and parallel, each the length of the sack. Curl both ends of each in the same direction. These will form the lip of the barrel.

Working on a layer of waxed paper, coat the outside curve of the wide strip with epoxy. Remove the excess epoxy by pushing it off with a dowel. Place the strip inside the barrel and smooth it against the wall with gentle strokes of a finger, away from the seam. If curled properly, the paper should stay in place. DO NOT put a 2-inch eyepiece into the barrel to form the shim; the epoxy will soak through the paper and glue the eyepiece in.

Coat one side of a 3/8-inch paper strip *thinly*, from inside one curl to within an inch or so of its end. Wrap it around the upper edge of the barrel, keeping it snug by gently

pulling on the dry end. Then epoxy the dry curl and press it down. Repeat the process with the next strip and so on if more are used. A cotton swab is an adequate applicator.

Place the barrel lip down on the waxed paper and press down on the edge of the strip with a knife blade. This will true it up to the edge of the barrel. Remove any excess epoxy and let the sleeve and lip cure for a day before sanding it with #220 carbide sandpaper.

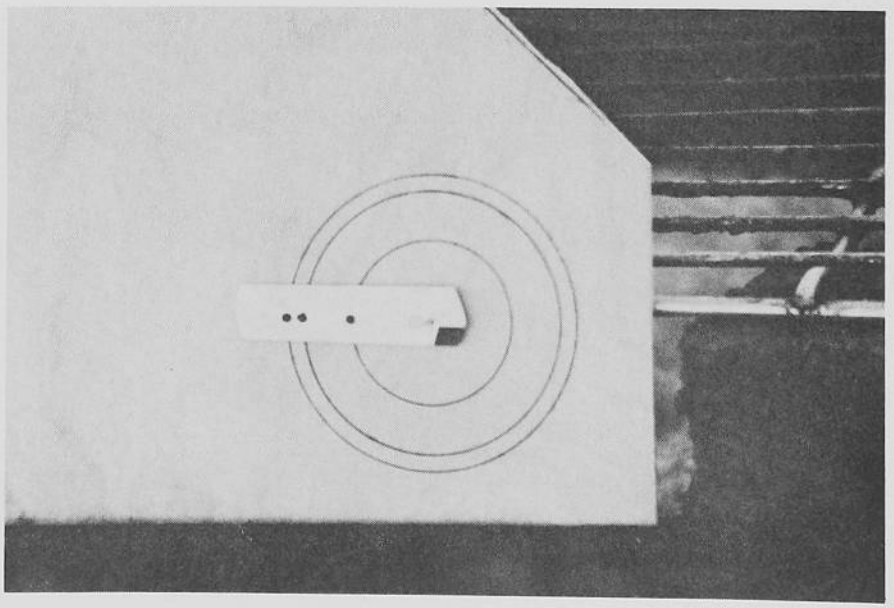
When the epoxy-filled nut has cured for eight hours, true the epoxy side by rubbing it on #80 sandpaper. Epoxy it to the plywood plate with the minimum of glue. Weight it and let it cure. When it's hardened, drill and tap the lip for an 8-32x1/2-inch brass roundhead bolt with a nut drawn up and epoxied. Back up the inner sleeve when you drill it so it won't be torn. The nut is drilled and tapped for a 10-24x3/4-inch nylon dragscrew. Don't try to run either tap through in one pass because it will clog. Remove the chips in several partial entries.

The Focuser Base

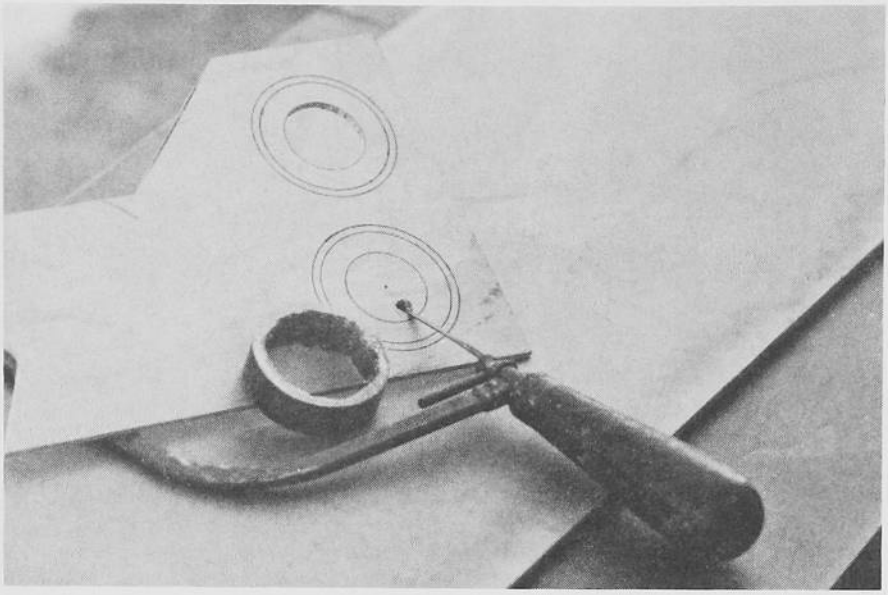
As the focuser's base, the nut will be oriented on the tube with two points of the hex indicating the long axis of the tube and two flats parallel to the sides of the tube. Drill holes for #8 mounting bolts just outside the corner portions of the side flats, perpendicular to the nut, whether for a flat or for a round tube.

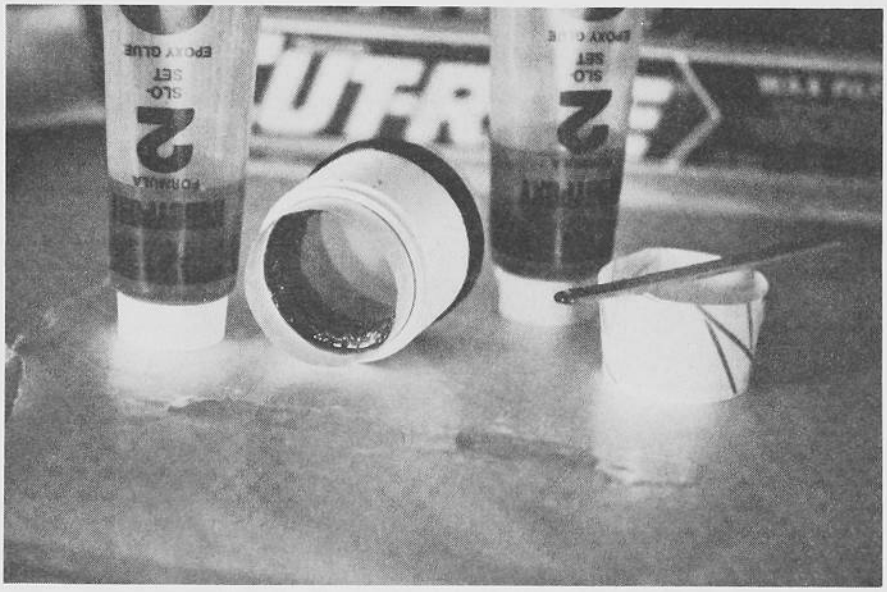
If your telescope has a square tube, finish the focuser with a final sanding, and paint the parts that can be painted. The white nut will not accept most paints. One sure way to permanently blacken its top is to glue an anular ring of black construction paper to it with contact cement and trim it off to the flats. This looks neat and won't peel off. Another is to use Krylon ultra-flat black enamel, a spray paint, one of the few paints which adheres adequately to the plastic of the deglossed nut. If it scuffs off, you can repaint it.

If your telescope has a round tube, the base must be curved to fit it. For a 10-inch OD tube, for instance, obtain a strip of spruce (another inexpensive aircraft item) 1/4-inch by 1/4-inch square. Place



Top: Carefully sever the valve at the flange. Middle: Fill the nut with epoxy. Bottom: Mark circles on plywood with a fixed-radius compass.





the strip under a side-flat of the hex and align it with the edge. Trace the angles of the corners on to the strip to make a trapezoid. Make another and cut them both. Glue the strips parallel to the sides of the plywood base under the mounting bolt holes. Fast drying glue is convenient for this job, if you have some.

Tape a sheet of #80 or #100 sandpaper to the telescope tube. The two strips of spruce can be rapidly brought back to the curve by stroking back and forth on the sandpaper. Roughly square the focuser radially and longitudinally to the tube by eyeballing a one-foot rule laid across the top of the barrel. (You'll have to square it on optically when you install it.)

Next tape a piece of waxed paper over the curve of the tube. Invert the base of the focuser and build a ridge of the material along the edge of those flats with wood filler, auto body filler, or a stiff epoxy-sawdust mixture, to fill the gap between the base and the tube. When the material approximates the tube's curve, press the base against the waxed paper form. Trowel on a bit more filler with a knife blade until all gaps are filled and there is a slight excess to allow for shrinkage. If any filler material approaches the threads, trowel it back with the knife blade. Weight it heavily and let it dry or cure. I used Elmer's wood filler I already had on hand; it's easier to use than epoxy-sawdust.

When the filler has dried or cured, rasp, file, and sand it to the contour of the hex, and then paint it. The curved focuser base is essentially finished except for drilling the mounting bolt holes all the way through the spruce strips. You can do this when you drill the tube for the bolts.

As described, this focuser will have a minimum height of 0.875 inch and a maximum height of 1.875 inch. It is truly an ultrashort focuser and makes possible a considerable reduction in diagonal size or a substantial increase in the fully illuminated field of a Newtonian without an increase in diagonal size. But not without problems.

Parfocalizing Eyepieces

If you happen to have parafocalized 1.25- and 2-inch eyepieces

Top: Cut the adaptor cap parts with a scroll saw. Middle: Allow the adaptor to cure inside the focuser. Bottom: Groove the adaptor cap.

(such wonders must be available), skip this part. All the 2-inch eyepieces I own have field stops far down the barrels, resulting in a great difference in focuser position between the 1.25- and 2-inch sizes—a greater difference than the 1-inch travel of this focuser or any of its commercial counterparts. Adding a focus extension tube, one solution, negates the benefit of having a really short focuser.

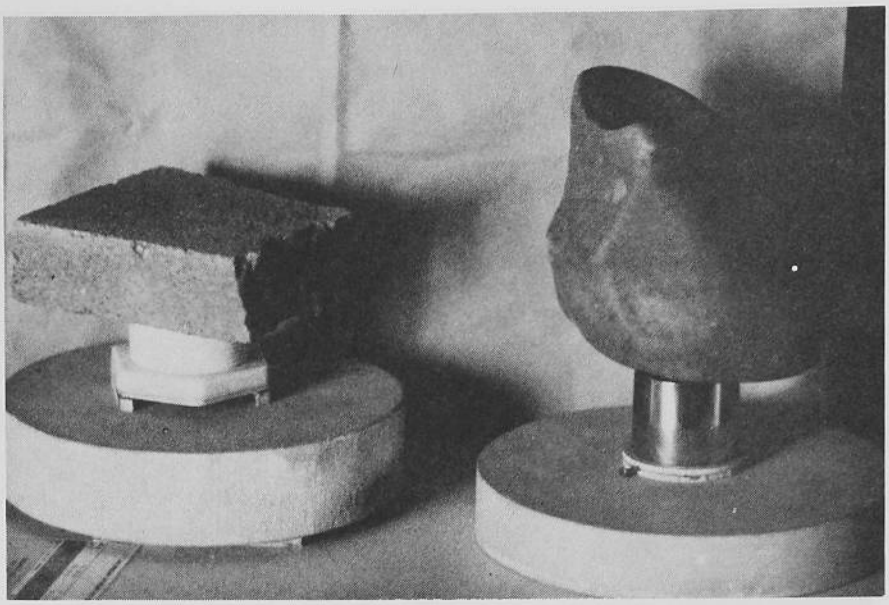
One way to fix this is by keeping the focal plane close to the tube, where a visual reflector's should be. Locate focus so your 1.25-inch eyepieces in their with adaptor focus near the inner limit of the focuser's travel, and make spacers for the 2-inch eyepieces so that they focus before the outer limit of travel is reached. Using a Barlow that requires more inward travel takes careful planning.

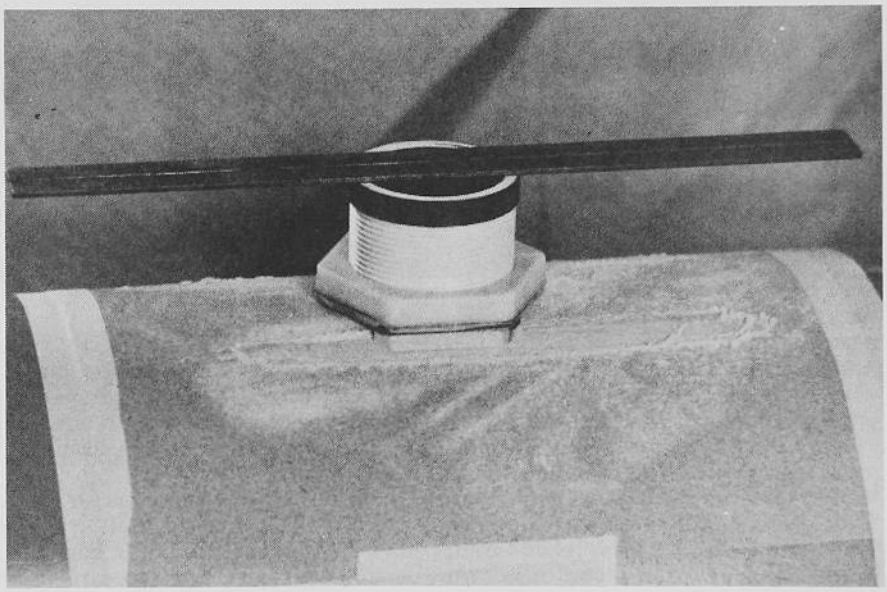
Adjusting the height of spacer is easy. Make spacers from epoxy-soaked soft felt, a department store fabric item. Wrap a bit less than two turns of waxed paper tightly around a 2-inch eyepiece barrel and tuck the excess into the ends of the barrel after securing with tape. DO NOT tape the beginning of the strip to the barrel because you won't be able to slide it off after the epoxy cures. This goes for the barrel's mold as well.

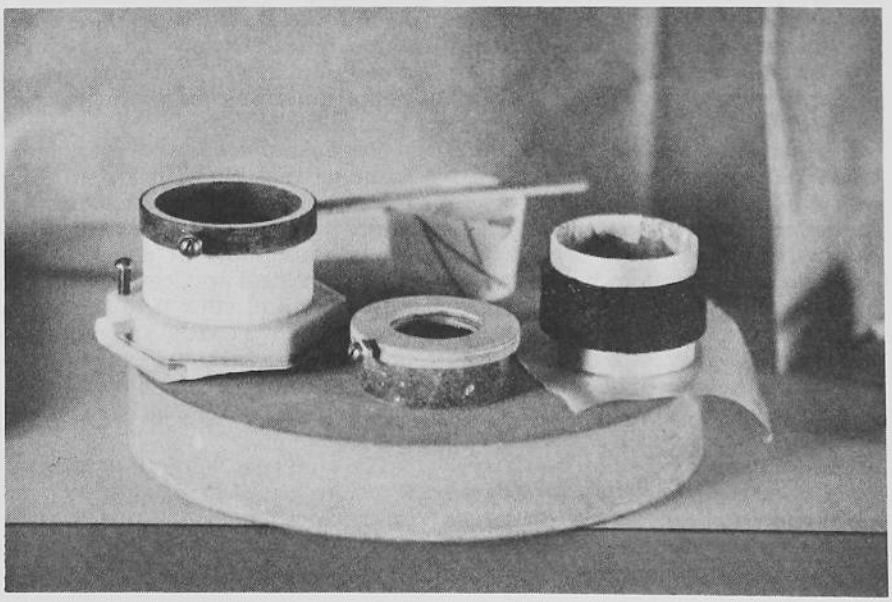
Cut a strip of felt 1/16 inch over the desired width and about 13.25 inches long from a paper pattern. Trim its length until it makes exactly two turns around the barrel. Lay the strip on waxed paper and coat the top side with epoxy. Keep applying until the strip remains glossy and sticks to the waxed paper. Soft felt saturates rapidly.

Wrap the strip around the protected eyepiece barrel, making one edge parallel to one edge of the barrel. After it has cured, leave the piece on the barrel and sand it down on #100-grit paper while you rotate it until you've "feathered in" the protruding end of the epoxy-felt strip. Slide the waxed paper off the barrel and remove it. Square up the spacer on sand paper until both ends fit against the eyepiece shoulder with no gaps. The wall thickness will be about 1/8 inch.

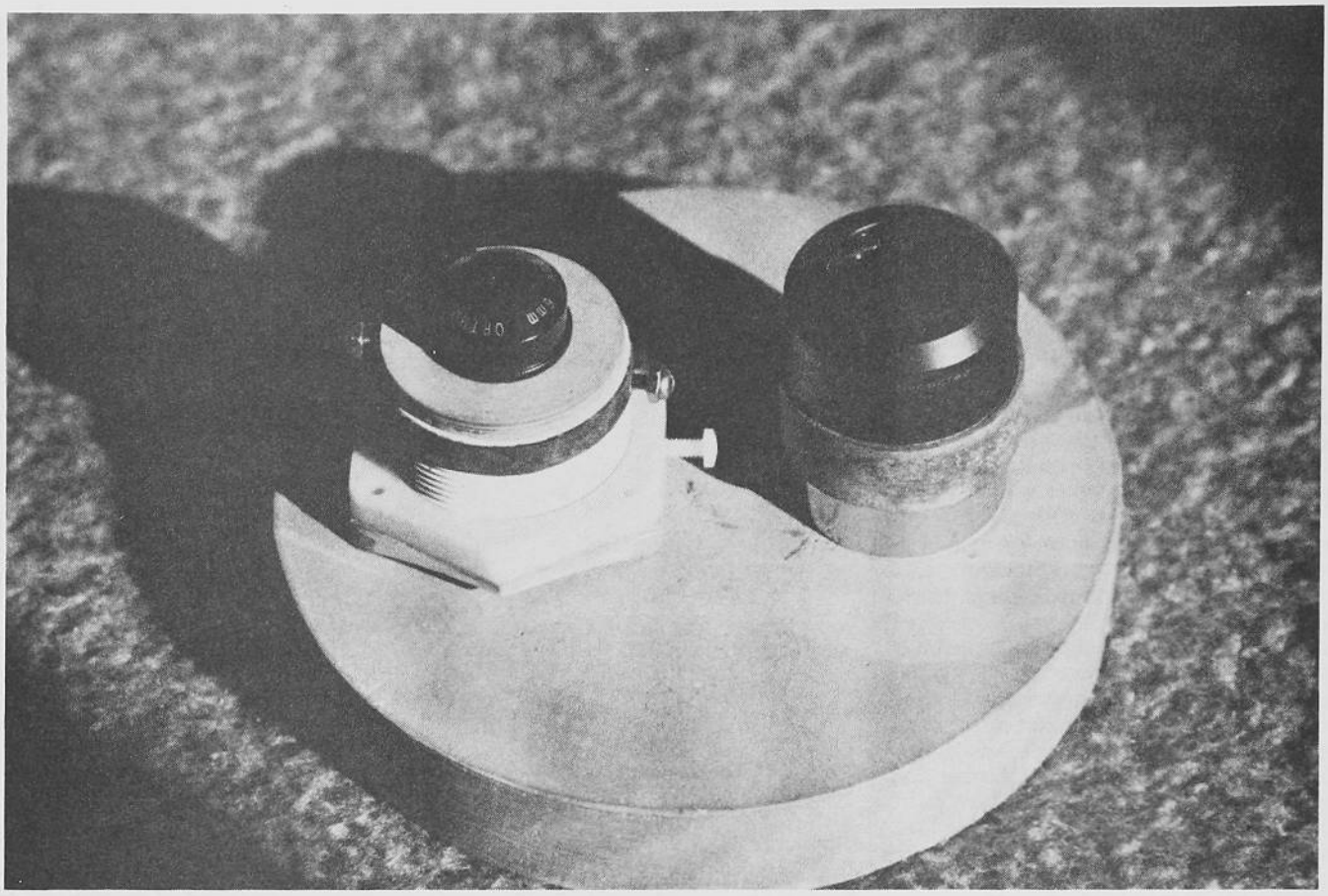
Narrow, longitudinal paper shims of a thickness that provides for a







Top: Epoxy the rails and cap halves. Rocks serve as weights. Middle: Sand the base to fit. Bottom: Cure the focuser and the adaptor.



The focuser with the 1.25-inch adaptor and an eyepiece. Beside it is a 2-inch eyepiece with a spacer on the barrel. The parts are unpainted.

snug, push-in fit for eyepieces are then epoxied inside the spacer 120 degrees apart. Kraft paper is about the right thickness for the shims; curl it before cutting the shims.

Epoxy-felt and epoxy-paper methods are useful for making many other telescope parts and accessories, from focus extension tubes to dew caps and lens cells—even finder tubes. Where you need an accurately concentric change in outside diameter, epoxy continuous strips of adding machine paper to the appropriate side of the tube.

An Eyepiece Adaptor

You can mold a 1.25- to 2-inch adaptor from a single thick strip of hard felt weatherstripping. When the epoxy cures, the dense parallel fibers materially increase the rigidity of the part.

Begin construction by cutting a strip of waxed paper 3 inches wide and 13.5 inches long. Trim the ends so the strip makes a bit less than two turns inside the focuser barrel. From a roll of all-purpose plain felt weatherstripping with a 5/8-inch by 3/16-inch cross section, cut a 7-inch length and roll it into a tight spiral. It will want to fold in larger increments at the inside curve, but fold these with your fingers to make many smaller creases.

Trim the ends so the strip butts snugly inside the focuser barrel. Epoxy will not cause it to swell as water would, so the length will stay the same even when it's saturated with epoxy.

Smooth the waxed paper strip against the inside wall of the focuser barrel, slipping it back and forth until there are no wrinkles in it or gaps behind it; then place a small piece of cellophane tape across the seam. This requires some dexterity, but the waxed paper must be made into a perfect form of the bore.

Mix a volume of epoxy roughly the same as that of the felt strip. Flatten the strip on waxed paper and apply a heavy coat of epoxy to the top surface only. (A popsicle stick will be an ideal applicator.) Turn the strip over and stick it to the waxed paper. Apply a coat to the other side only. Try to keep the glue off the sides of the strip; the side tells you how far the epoxy has soaked into the faces.

The glue coat will lose its gloss as it soaks in. When it turns dull, apply another coat to the surface, turn the felt over, and apply another coat to that surface until the felt takes no more epoxy. Because it may take thirty minutes to saturate the strip, use at least forty-five-minute setting epoxy. When there is little dry area left on the sides of the strip, coat them and the ends and allow a bit more time for saturation. You should wind up with the curved side of the strip up.

Roll the strip up until it has about a 1/2-inch overlap at the ends. Grasp the lap with an old pair of scissors or needlenose pliers and place the strip inside the protected focuser barrel at the bottom end (in case you haven't made the top end perfectly concentric). Press in against the wall with the popsicle stick and butt the ends. Handle the threads with dry fingers only. Remove epoxy from the scissors or pliers before it sets with alcohol or lacquer thinner.

Although the protruding waxed paper sleeve gets in the way, adjust the felt strip until it's even with the end of the focuser barrel and thus close to being square with the bore.

Fortunately, internal beauty is unnecessary.

The adaptor cap is made from the model aircraft plywood. With a compass, draw two sets of concentric circles on it: one having radii of 5/8 inch and 1-1/8 inches, the other, 5/8 inch, 1 inch, and 1-1/8 inches. The 1.25-inch and 2-inch circles can be plus a couple of thousandths but not minus.

To make accurate circles, construct fixed radius compasses from a thin stripes of cardboard or wood. Drive a sharp nail in for the center point and drill 1/16-inch holes at the desired radii. The holes should be just large enough to just accept the point of a ballpoint pen. To use the compass, drive the brad through the wood and draw a widened radius line on the back of each piece. Test the compass on cardboard before you mark the plywood with it.

For the adaptor cap, cut out the inner then outer circles with a coping saw or sabre saw with a scroll blade. If the 1.25-inch circles are cut just to the line or inside it, the holes can be made quite accurate by turning them on carbide paper with a dowel—I used a broomstick held across my knees while sitting on the steps—until your largest 1.25-inch eyepiece barrel just pushes in.

Groove radial lines to equal depths on the backsides of the plywood rings with a hacksaw blade, so a small finishing nail can be pushed through the matching grooves and into the central holes when the rings are pressed together. The nail hole will guide the tap drill for the setscrew, which will allow you to drill a hole between the two halves of the thin cap without error.

When the cap's halves have been closely fitted to the 1.25-inch eyepiece barrel, lay the one having the 2-inch circle on it on a board, circled side up. Within the 2-inch circle, drive two sharp nails into the piece but not through it, one on either side of the hole but not exactly at 180 degrees around it. Thin 1-inch-long nails are good.

Place the other piece on the eyepiece barrel and the nailed piece on top of it. Adjust the rings so they are perpendicular to the eyepiece barrel—no problem with a tight fit. The end of the eyepiece barrel should be flush with the top piece (the one you've driven the nails into) and with the finish nail in its common groove.

Things Few TMs Have on Hand

"Master Plumber" flush valve $5.49
Plain 5/8-inch by 3/16-inch weatherstrip $1.89
1/8-inch model-aircraft plywood $1.25
Spruce strips $0.60
Nuts and bolts for this project $1.40

Things Every TM Should Have

Slow-curing epoxy glue
Waxed paper
#10-24 and #8-32 taps and drills
Large paper grocery bag
Cellophane tape and masking tape
Small nails and brads
Popsicle stick
Paper cups for epoxy
Sandpaper and carbide paper
An understanding mate

Place the sandwich on the edge of a bench or table and drive one brad into but not through the ring beneath. Check perpendicularity and drive in the other nail. Very little depth is necessary because the brads only act as locator pins.

Separate the pieces and epoxy them together, using the nail points to relocate them properly. Use a minimum of epoxy. Place the unit on waxed paper under a heavy weight on a 2-inch eyepiece barrel. Remove the finish nail from its common groove before the epoxy sets, and remove excess epoxy from the 1.25-inch hole with a cotton swab in the early stage of curing. When it's cured, clear the hole on the cap of excess epoxy and enlarge it with sandpaper on a dowel until your largest 1.25-inch eyepiece barrel falls into it by its weight alone.

The cured epoxy felt-ring that forms the adaptor barrel should be finished by squaring its ends on #100 grit sandpaper and buffing its sides on #220 carbide paper. The barrel is aligned with the 2-inch circle and epoxied to the cap. Use a minimum amount of epoxy and drag the outer bead across the wood with a knifepoint, so you can see the 2-inch alignment circle.

I went no farther than epoxying the cap and barrel together. But owners of tall, heavy eyepieces should consider further strengthening. One way that works nicely is to draw the 1.25-inch holes a couple of thousandths oversize, so when you've trued them they will pass a waxed-paper-protected eyepiece barrel as most commercial adaptors will. Finish by pouring in epoxy or epoxy-sawdust around the protected eyepiece barrel, your smallest in diameter.

Drill the setscrew hole gradually, with bits of increasing size, up to the tap drill for an 8-32x3/4-inch roundhead brass bolt, like that of the focuser.

I have successfully used the same method of construction to make end caps for 2-inch and larger finder telescopes. I have also tested the bond strength of paper epoxied to the two types of plastic found in these valves after deglossing and it stuck very well, but wasn't truly bonded because the epoxy could be scraped and pried up with a knife blade.

The key to making such bonds work is the same principle as making good solder joints: parts that stay together by themselves. The epoxy-and-paper lip and sleeve are concentric cylinders "locked" in place by epoxy that has molded into the deglossing scratches, into the small, imperfect ring in the barrel's bore, and the partial thread and edge chamfer under the lip. For larger, heavier structures, make more "locks" with a drill point.

For those who insist on a genuine glue bond, apply the sleeve and the first layer of the lip with a tested plastic cement. Both of the materials in the valves (one opaque and one translucent) are glueable; the valves are cemented to an overflow pipe. That's for the perfectionists: I think the epoxy-and-paper parts of my focuser will stick around longer than I will.

Don Scott
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Constructing a Low-Cost 6-Inch f/21 Littrow Refractor

You don't have to be afraid of making a refractor.

I know there are many other optical systems, each with its own strengths and weaknesses. However, if refractors still fascinate you, but you feel they're an impossible system for an amateur to grind and construct, perhaps your negative assessment results from certain perspectives and trends. For a refractor, you suspect, you'll have to have a lathe, memorize trigonometric tables, obtain financing for glass with rusibium in it, and know a wizard in the woods you can turn to when the way turns bleak and foggy.

But consider how challenging and rewarding it was to grind and build a Maksutov. Remember how interesting it was to develop skills and techniques for photographing nebulae and galaxies. Think how fascinating it is to see with your own eyes the arms of galaxies. Isn't it reasonable to think building a refractor has a good side to it as well?

If you have patience and a micrometer, a refractor is a realistic possibility for a great scope. With limited funds, I built a 6-inch f/21 refractor. It gives superb images and is the best telescope I've ever built. I feel with this scope I'll be observing more again.

Mr. Kundrat, a seventh-grade science teacher, and Comet Ikeya-Seki sparked my interest in astronomy. In 1974 Professor Lindblad of Dana College encouraged my study of Comet Kohoutek and grinding of 6- and 8-inch mirrors. A few years ago an ad in *S&T* put me in contact with David Cartwright, who produced blanks and encouragement to try a refractor.

In the twenty years I've used telescopes, I've ground a few mirrors, owned a couple of popular commercial scopes, and used a lot of them. It was confusing to compare claims for various telescopes with the results.

Scopes with supposedly high-quality optics didn't always perform as expected. Certain optical systems almost guaranteed good performance despite "poorer" optics. Some systems seemed to have flaws you just couldn't get around. For example, I was optically happier with my 8-inch f/7 Newtonian than an SCT I owned.

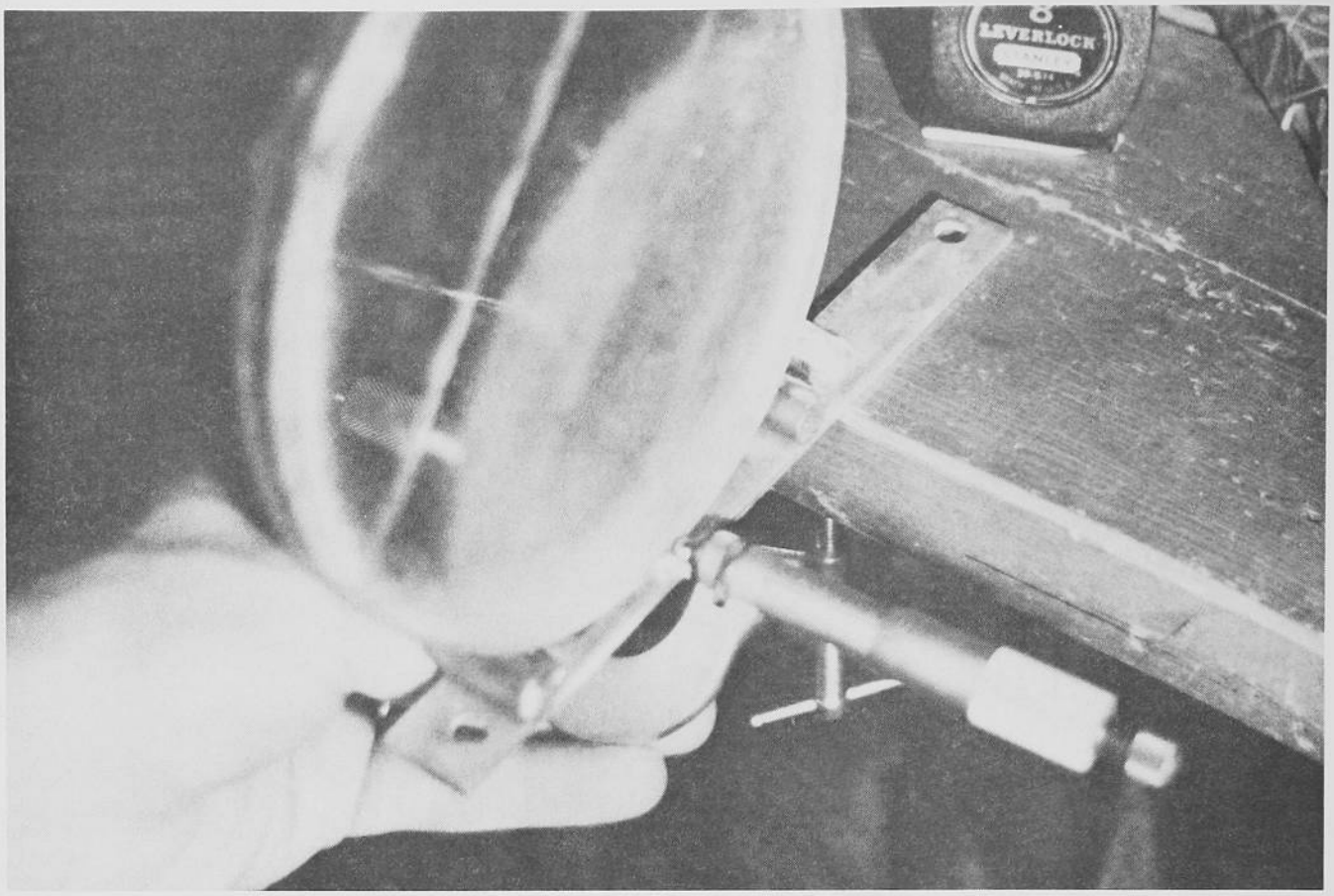
Eventually, as an experiment in affordability and performance, I built a 4-inch f/24.5 Herschelian. This telescope really pleased me. Despite obvious disadvantages of less resolution and smaller light grasp, the Herschelian gave the 8-inch Newtonian a real run for the money. It seemed an unobstructed system gave a bigger jump in performance than theory would indicate.

A friend and I went in on a 17.5-inch mirror, but we soon traded it for a 6-inch f/15 refractor objective and were both much happier. People who had never seen through a telescope before could see the spiral arms of M51 with this achromat. It seemed unobstructed scopes with long f/ratios could perform beautifully on deep-sky objects and were very sharp and contrasty on the Moon and planets. However, that telescope was stolen.

My humble Herschelian has given better performance than scopes twice the size with supposedly higher wave ratings same night, same time, same objects. The star images were beautiful pinpoints clear across the field. Diffraction rings were clearly evident. At 400x the Moon was a dim image, but an image not at all lacking in sharpness.

The ad that interested me in refractors was from a British firm called Amateur Optics. (The address is Amateur Optics, David Cartwright, Tynessa, Clyro, Hereford, Great Britain, HR3 6JV. The introductory pamphlet costs one dollar.) The firm was started by David Cartwright, who sold Chance Pilkington glass from England. David suggests using a design the Clarks used. The

Basic materials and hand-made components keeps costs down in Andrew Sorenson's 10-foot refractor. The mount remains outdoors.



Controlling wedge is essential for a successful objective lens. The micrometer measures the thickness of the lens plus two ball bearings.

crown lens is equiconvex and R3 has the same radius but is concave. R4 is flat. His pamphlet assumes you know the basics of grinding, so is short but to the point. Although I obtained some additional information from the instructions in a Norm Remer refractor kit, I suspect a person with nothing except David's pamphlet could finish a Littrow refractor. ("How to Make a Lens" in *TM#3* details standard methods for making refractor lenses, from cutting raw glass to having the finished objective coated. —*ed.*)

Grinding I had the glass for a year and a half before I seriously started work on it. If you've ever ground a mirror, you already know a little of this fear. "There must be something I'm forgetting or unprepared for," you think, "It just can't be this 'simple'."

Finally I just decided I was ready and started work. Grinding itself isn't any different from grinding a mirror, I discovered, but there are a few extra things—wedging, astigmatism, and scratches—that you must watch closely.

The blanks I received were 6.188 in inches diameter and pre-edged by Amateur Optics. The tools were 6 inches diameter.

Grinding Board For grinding I made a simple jig to hold both sizes. It consisted of three thin pieces of plywood stacked on a board. The bottom piece had a 6-inch hole to hold the tool. On top of that I put a square with a 6.063-inch hole for the tool, which fit through this piece of wood. On top of that I added another plywood with a 6.188-inch hole. The 6.063-inch wooden annulus held the blanks at the edge and kept the non working surface from scratching. I put them all on a board with wood screws, let a coating of oil soak in, and scrubbed them down with clean water and a toothbrush between abrasives or when necessary.

This grinding board was quite portable. I'd sit on a chair with the board on a brick-filled bucket or more generally sat on the floor with the board in front of me. It worked out well. I even took it on vacation. It was a lot of fun to use. Even the large bucket at my side to hold rinse water and came in handy one day at my in-law's apartment when a neighbor's '65 Dodge caught fire under the hood. You think grinding is boring?

Grinding Tools Grinding could be done crown on flint with the Littrow design because R2 and R3 are the same. But let's say you put a scratch in one or the other. Grinding it out could change the radius or wedge of both. Therefore, I chose to have separate tools available as well. To start with, I got all curves where I wanted them and got wedge within reasonable limits. If a radius started to vary, or wedge started to increase, I'd go back to the tools that were already close to the desired radius or grind the tools on each other to get them right. I tried to keep all surfaces at proper radius and spherical.

Let's say only one surface involved is a problem. Having a spare tool saves you from involving a second surface of the lens. For example, suppose it's early in the morning and you're going to work R4. (Not that this happened to anyone in particular, anyone can make a mistake.) You're not awake yet when you set R4 down on its tool. The abrasive doesn't sound right at all, so you take a few more strokes

to distribute it better. That's when the Sun rises and you notice it's R3 you're working.

R4 is supposed to be flat, but I think as long as it's close to flat, getting it smooth is more important. I used small abrasives, several plates of window glass, and low pressure for grinding R4. The rotation was something like this: R4 on window 1, R4 on window 2, window 1 on window 2, window 2 on R4, window 1 on R4, and window 2 on window 1. I used a straightedge to inspect for radius or lack of it. I put the 7-inch-diameter window glass directly on the grinding board when it was below R4. Moisture on the board held the glass, but removable cleats could be placed on top of the board.

Wedge Wedging is one of the biggest phantoms that haunt the literature of the achromat. Around the lens circumference, the thickness of the blank should not vary by more than 0.001 inch, or the white light will be passing through what would be a prism. I got it under control early and watched it closely till at least 400 grit. I worried about wedge, but it turned out to be a reasonable task. After all, you don't have to eyeball it.

There are two parts of the wedge problem. One is measuring the amount of wedge, and the other is controlling it on the grinding stand.

If you have a dial indicator that reads depth to tenths of thousandths of an inch, fine. I didn't, so I used a micrometer that read to tenths of thousandth of an inch. I also used an old 1-inch micrometer that read to thousandths, which I bought for $1 at a yard sale in Davenport. Both gave similar readings.

I kept a uniform chamfer on the edge of the flint element and measured it directly. Early in grinding the crown element, however, the curves become strong enough to make accurate readings difficult to obtain. I used a simple jig and ball bearings to get accurate readings.

I set the blank on a thin strip of steel, say an angle iron, clamped to a table or box. (Underneath, of course, is enough cotton to knit an elephant sweater.) On one side of the strip, I superglued a ball bearing from a bicycle front hub. The blank was set on edge close to the ball bearing. Then I placed a second ball bearing on the other side of the blank and brought the micrometer up from underneath. (Holding the second ball bearing got to be like eating peas with a knife, so to corral it I glued a loop of string to the side of the springboard.)

Using this technique, the bite of the anvils was on either side of the thickest part of the ball bearing and a consistent distance from the edge (or up from the bottom in this orientation) of the blank. When the anvil spun in against the bearing, I was careful that the spin pushed the bearing down against the springboard. After a bit of practice, I could do this with little trouble. It is possible to roll the bearing up the side of the blank and get a bad reading. I numbered with a permanent marker six points around the rim of the blank and took readings at those locations.

I used a variety of techniques to control wedge once I had measured it. Let's say the flint was thick at position 4 on the rim. With R3 faced up, I placed the center of the tool over position 4. I used a tangential stroke to bring the wedge down quickly. Another technique was to place the center of the tool directly over the center of R3. Using position 1 as a pivot point, I moved position 4 slowly back and forth in an arc on the tool. Alternatively, I ground center over center with more pressure over position 4 on the flint.

I always rotated the tool. During normal grinding, make certain to rotate your lens blanks so that astigmatism isn't ground in. Check wedge frequently and you'll find which techniques work well for you. If my readings are accurate, my lenses have wedges of 0.0006 inch and 0.0002 inch.

In one reference, I read that the thickness of the lens can slightly lengthen the focal length. It didn't specify much more, so I ground for 125-inch focal length, and hoped to end near 126 inches. The final focal length, as measured by a quick check with the Sun, was 125 inches. I'm sure for optimum performance, thickness of lenses must be taken into account with other designs. Here the Littrow is a little more forgiving.

Scratches To prevent scratching the lens while I was working on the other side, I ground all four surfaces with one abrasive before going on to the next abrasive. I didn't begin work on the flat surface, R4, until #320.

Polishing I had read that for polishing 6-inch or smaller diameters, you don't need pitch-lap facets. I had tried polishing without facets on the Herschelian and had a terrible time. I tried polishing the 6-inch without facets and got just about nowhere for hours. I began to wonder if this was where it was worthwhile to mortgage your house to get glass with rusibium in it. Crown and flint evidently don't polish out like good Pyrex.

Later, when talking with James Daley, he said he used facets even on smaller diameters. I went back to procedures I normally used on the 6- and 8-inch mirrors, and the blanks quickly started clearing up. I used pitch a little on the hard side. By the way, use the separate tool as the base for pitch laps.

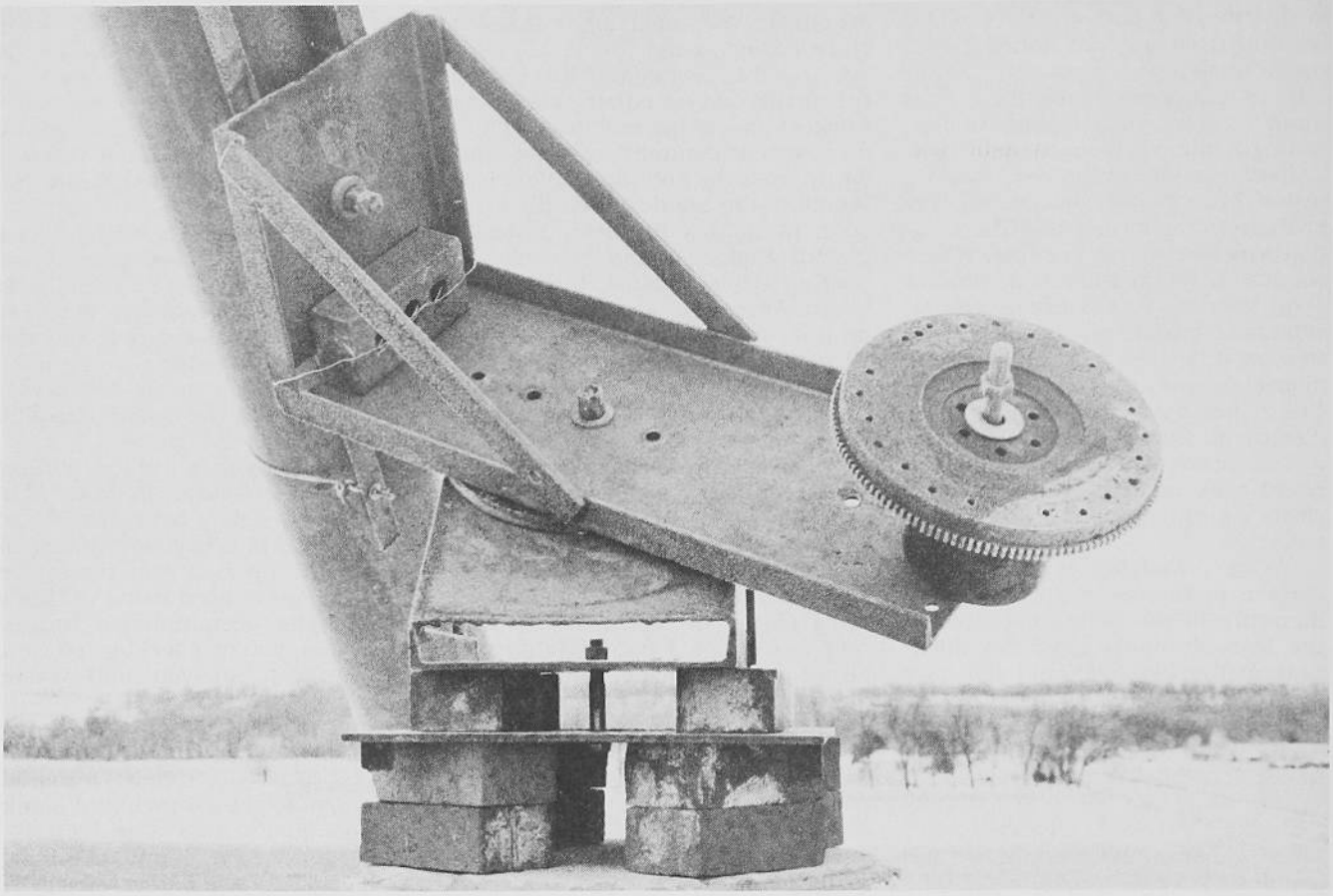
Testing There's a thrill to putting a mirror on a stand in front of a tester and seeing a beautiful sphere or parabola, but, boy, seeing optical glass clear up is a real rush. The eyepiece you've been using to check surface pits does unusual things. You think you're checking pits on the surface, but you find you're checking pits on the far side.

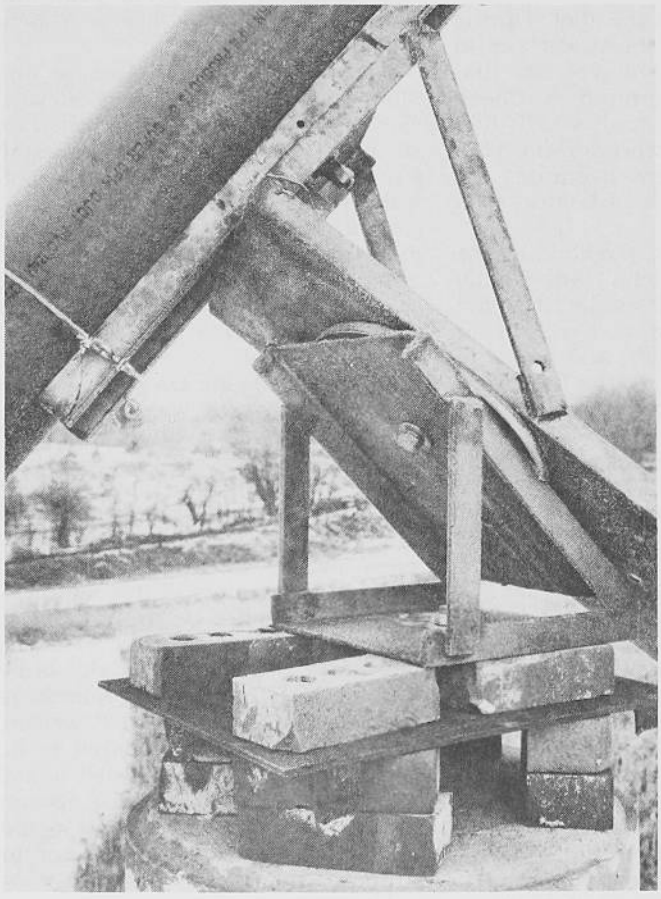
Thousands of years ago, Egyptians valued glass more than diamonds. Just a couple hundred years ago, to get a 4-inch flint blank of good quality was a real prize—careers depended on obtaining them. Some of the old technology is still beautiful and gives beautiful results. The lens is like a 6-inch diameter diamond.

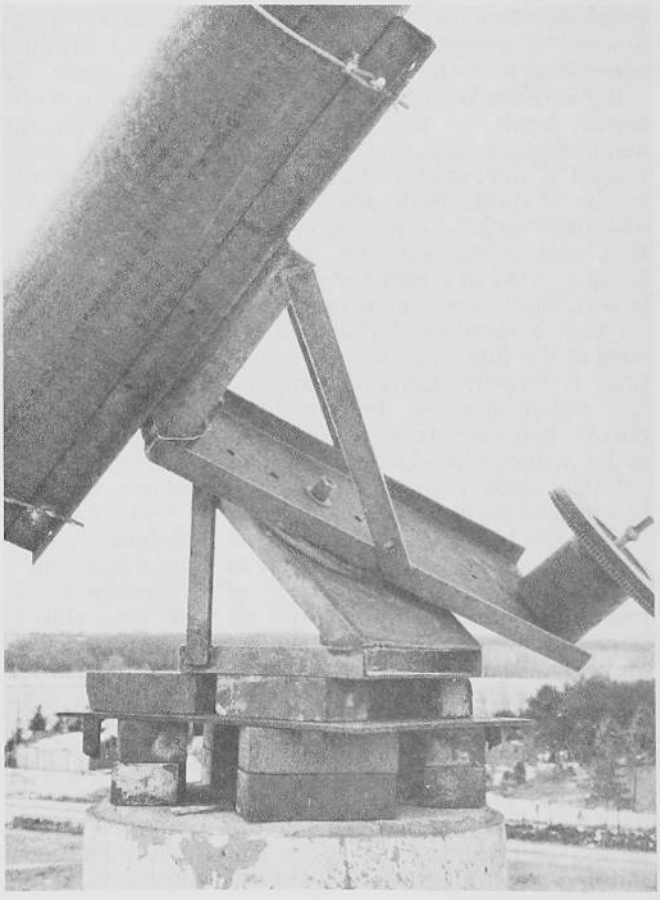
So the lenses were clearing up, Mars was great, and Astrofest was close. I had to polish but wanted to see how it performed. For a pedestal I used some PVC pipe about a foot wide that a friend and I found discarded and half buried. A steel air duct pipe I bought from a local business for $10 became the telescope tube. Bridge plank and bed frames became the base and brace for the pedestal.

Equatorial Mount On previous telescopes I've spent weeks trying to build a good heavy-duty equatorial with simple tools. For this telescope I used a 12-inch wide channel iron. The idea is that wide, flat steel slides against wide, flat steel. The axes swing on 5/8-inch bolts through the centers of the channels with white grease between giving a reasonably smooth motion.

Atop the pedestal is a wedge built with channel iron with a hole in it so a channel-iron "dogsled" welded at right angles can be bored to it. The long base of the dogsled has a counterweight on one end. Some narrower channel iron with angle iron welded to each side (better to support the tube assembly) is







bolted through the upright channel iron on the other end. Holes in the angle iron and rope hold the tube assembly to the mount.

I wired a PVC floor flange base and an old 1.25-inch plastic friction-fit Edmund focuser to the lower end of the tube. Nine bolts and three angle irons attached a fiberglass lens cell I bought from David Cartwright to the upper end. The mount was welded together in less than a day. Jim Axness of Perry, Iowa, helped me assemble the pedestal in one afternoon. After two years of trial and error, I felt I had successfully built a solid mount for a large scope using simple tools.

First Light I didn't have the focuser on yet but couldn't resist looking to see how things were. We hand held the 1-inch eyepiece up to see Saturn. It certainly looked good. After a little looking at Saturn, I decided to move the scope to a nearby star to see how good focus or diffraction rings were. What a letdown: the star refused to focus. Then I realized that I shouldn't, under normal circumstances, expect stellar focus of a distant, greenish planet like Uranus!

Real stars proved sharp. After putting on the focuser, I went to Astrofest and had a blast. Later I used a 6-inch flat and the old tube with lens in place to test the lens. It was within limits of acceptable spherical aberration.

New Tube Back at home after Astrofest I started trying to complete the scope. The air duct had a 6-inch inside diameter and was shiny. Bob Cox once said a coiled wire inside the tube was a good baffle for a tube. The spiral winds inside the steel tube simulated this, and I hoped had helped to darken the field of view.

But meanwhile Jim Axness had found a source for 8-inch PVC tubing. Although it was heavier, it was easy to work and the 8-inch diameter gave better optical path clearance. Furthermore, it was wide enough to make it difficult for reflected light to reach the eyepiece.

For the new tube, I cut wooden adaptors and soaked them with hot paraffin. The focuser is bolted to one adaptor. The other has three bolts drilled through it to hold the lens cell. I put one screw through the tube into the 3/4-inch pine adaptor. I then aligned the lens with the tube horizontal and with a cloth draped over the end to darken the lens. At the focuser end I held a light near the center and observed its reflection during horizontal or vertical motion. I then maneuvered the adaptor until I had centered the reflection of the light on the lens. I then drilled two more holes in the tube and ran in screws to keep the adaptor and lens in place. (Thanks to James Daley for his suggestion.)

Twelve-inch steel channels form the structural elements of a massive equatorial mount. Declination "dog-sled" carries scrap counterweights.

Mounting I constructed a permanent pier from three rejected cement tiles 30 inches high each. Below them a hole about 5-feet deep and 3.5 feet wide is filled with rubble, rock, and cement. I filled the tiles with sand and cement and bolted the mount to the top, roughly polar aligned. I replaced the rope holding the tube on the mount with vinyl-coated steel cables.

This mount withstands wind better than any other I've built. When I change eyepieces, the object isn't lost. It's quiet and fun to use. I hope to add a weight drive with steel cables, bricks, and sand to this mount. Already there is a thick steel disc between the wedge and the dogsled.

The Latest Improvments I had hoped to make a new lens cell, but a mad dash to work on my bicycle, a tail wind, and a rock in the road slowed my astronomical work this winter, with a collarbone-crunching crash-and-burn. I made a wooden focuser for 2-inch eyepieces. A length of scrap 2-inch aluminum tubing holds the eyepiece. I rasped a pine collar to hold the tube snugly. Because the hole didn't turn out perfectly square with the tube, I pushed the collar into the tube, squared it up, and rasped it until the top was flush with the end of the tube. I then bolted the collar to the tube.

I'm still upset over the theft of the original 6-inch f/15. I remove the lens after each observing session. To keep the fiberglass from chipping on the three bolts of the adaptor, I filed one of the holes out so the cell would fit better in cold weather. I've discovered that tightening the bolts finger-tight works well, but overtightening them distorts the cell and causes flair in the images. The portable cell works well and the lens stays accurately aligned each time I put it on.

Alternatively, I'd like to find a way to lock the tube assembly to the pier with the cell on the tube assembly, or build an "observatory" with walls and some sort of roof and a door I can lock. I want to prevent another theft, but I also want to have the scope easy to use.

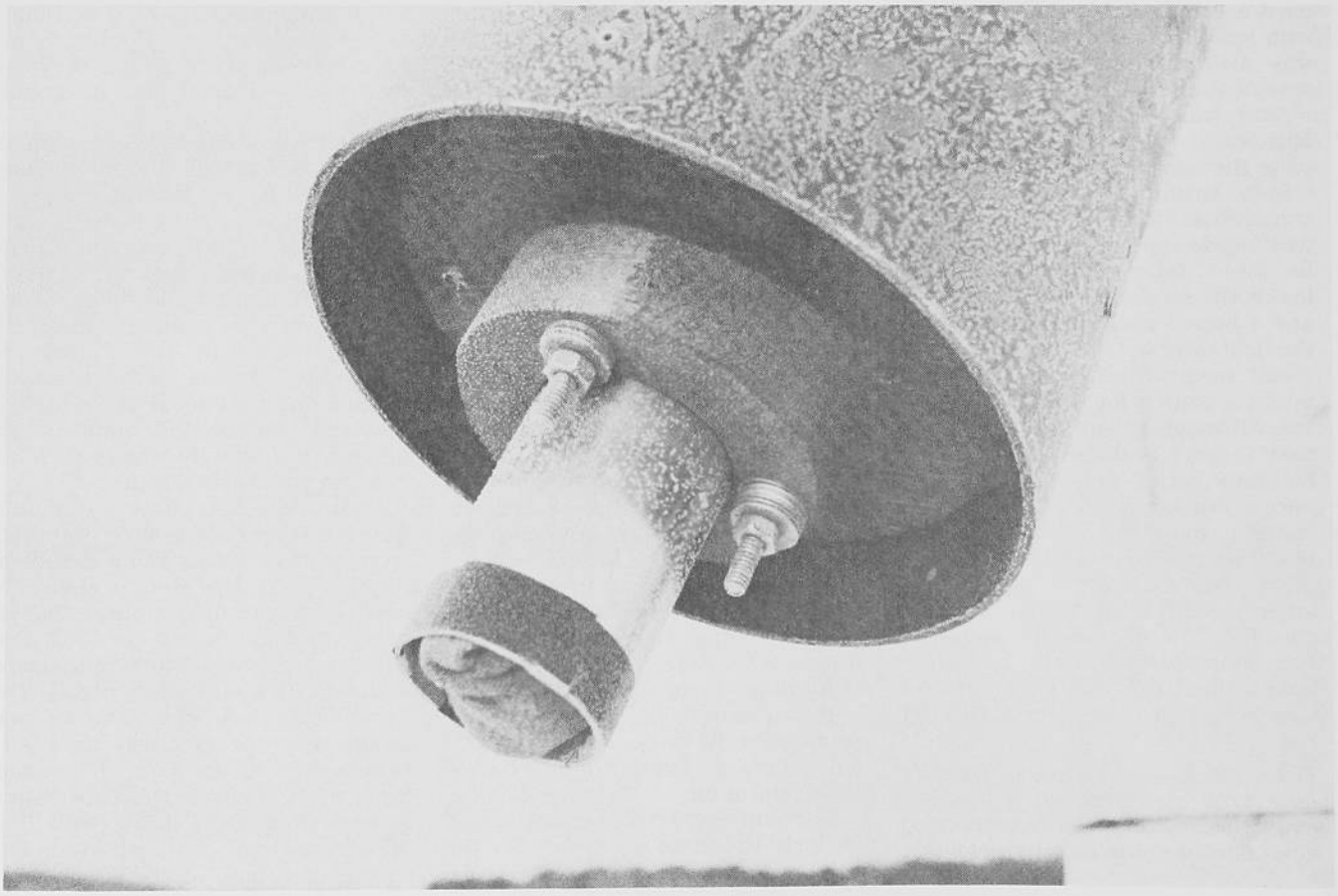
Performance I'm happier with this scope than any other I've owned, though it would be nice to have a drive. Atmosphere, rather than optics, generally limits the scope. Taking the cell off each time also hinders its use, but is becoming to be much less of a problem as I get experienced.

I once read of someone going around a star party with a Ronchi screen to get an idea of optical quality on different scopes. When an owner of a commercial scope found out, he said he didn't want his scope tested—he was happy with it as it was and didn't want to know. I don't want to be careless in working my glass, but I do want to feel contented.

With the refractor the contrast is so good it seems to perform like a much larger scope. Diffraction patterns can be seen around the stars. I've also improved the wobbly focuser people saw at Astrofest. The blanks are no longer air-spaced, but instead have oil between them. I understand spacing would help, but for more than very small spacing I'd need a different cell. As it is, I don't notice reflections. Coatings are expensive and I've heard they cut contrast, so I don't plan on getting them.

Most of the time I observe with an old Jaegers 32mm Plössl. It gives 100x and is my favorite eyepiece, but if seeing is good, I use a 12.5 symmetrical (250x) or other eyepieces. Splitting Epsilon Lyrae is easy at 100x, and Castor has black sky between its components. There are six stars in the Trapezium. Deep-sky objects are beautiful despite the f/21 focal ratio. M13 is resolved across the middle and lanes are distinctly visible in M31. Accurate focus seems easy.

Four-and-a-half days after first quarter several of Plato's craterlets were visible. I saw more detail on Jupiter with the 6-inch than I've seen with any of my other scopes. I've seen detail *inside* the Great Red Spot, numerous bands, and some festoons (it was a calm night). The lunar limb or a bright star beyond focus shows a greenish haze and violet inside focus. The small amount of chromatic aberration gives a view that I think rivals that of an unobstructed reflector. The moons of Jupiter are distinct discs.



I know now what was meant in *ATM Book II* when it was said a refractor could more easily be made than a reflector. It may be more work overall, but the possibility of good results are worth the extra work.

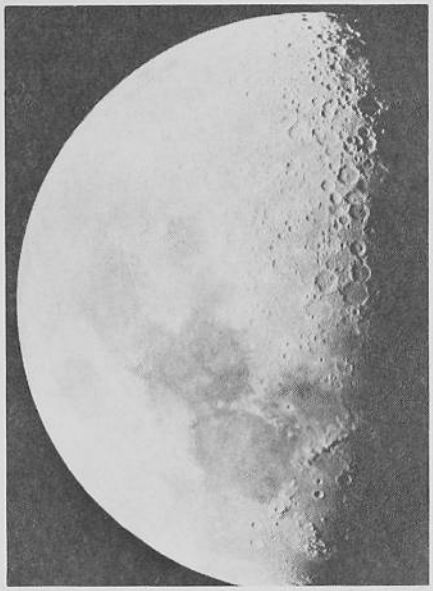
Advice for Others So what specifically do you need to make a lens? I've described much of what I've used and how I used it, but maybe the emphasis isn't clear. I'm excited with this scope because I think the refractor has been grossly overlooked as a good amateur project. The minimum equipment necessary is two blanks; four tools (two of then flat); two ball bearings; a micrometer; and the abrasive, pitch and rouge (okay, cerium oxide). I think if you work carefully and know what proper diffraction rings and patterns look like, you could star test. Heresy? Maybe so, but the star test is cheap, it works, and it's fun.

You'll also need the Sun. Because I frequently ground R1 and R2 on R3, I assumed the radius of R3 was the same as R1 and R2. I'd test R3 focus on the Sun several times and felt I could get within 1/8 inch in measuring the radius. Just remember R=2F. For some reason I enjoyed using the Sun to measure focal length, maybe it's the optical counterpart of riding a cycle without a helmet. I frequently checked the flat with a good straightedge. I think whatever radii you use, the main thing is to keep them smooth and spherical.

You'll need time. I haven't totaled the hours, but I know it was over two hundred hours. Enjoy it while it lasts.

As for cash, the scope as I took it to Astrofest cost less than $200, not counting the optical flat (which I hadn't used at that point) or the micrometer (which I'd had for ten years). I'm not giving a lot of dimensions except to give an idea of mass or general size, because if you build with scrap parts you'll undoubtedly find different materials. Because of pound-to-dollar changes, the cost of blanks is now between $150 and $160. A cell may be $20 or so.

And you need a design. It is my understanding that David Cartwright sells a particular combination of glass well suited to this



"Portable" lens cell means the telescope structure can remain outside while the sensitive lens is protected. Focuser is a simple sliding tube.

design. Other glasses may work but will not be as well corrected. What do you need to design a Littrow objective? 2.386. It's almost that simple.

Quoting David Cartwright, "To calculate the radius of curvature of the curved surface divide the desired focal length of the telescope by 2.386, or 42 percent approximately." Because all curved surfaces have the same radius, the next most difficult task would be to find the radius of the flat!

Most refractors require precise control of four radii. The Littrow is forgiving here. Being off a little on radii merely lengthens or shortens the focal length.

One of the weaknesses of the Littrow is coma, four times as bad as that of a Newtonian. If you make it too short, coma will be evident or even disastrous. Theoretically, a 6-inch refractor with less than 1/4-wave of chromatic aberration must be longer than f/20. A 6-inch f/10 Littrow would have a lot of color and as much coma as an f/5 Newtonian, neither of which interested me. The design becomes well corrected at f/21 and can be accomplished by an amateur.

I've often heard you need a lathe to build a refractor. I bought a fiberglass cell from Amateur Optics, but I think a person could build a cell without a lathe. Either way, you need to know what a cell does. This is not your father's old reflector!

A cell should have three points under the flint to support the lens. Six plastic screws should be located around the circumference 120* apart. The upper three locate the crown. The lower three locate the flint. You need a method of retaining the lenses in the cell and then attaching the cell to the tube. (It's also possible to mount a lens with tape and place it in a wooden cell. See the refractor chapter in *Build Your Own Telescope.* —*ed.*)

Prepare yourself for some big letdowns when you first put things together but don't give up. Pay close attention to the out-of-focus star images. Astigmatism probably means your cell, focuser, or both are not square with the tube or optical axis. Flares in focus or triangular diffraction patterns may mean the retaining ring, lateral ring, or lateral (locating) screws are too tight.

Different colors on opposite sides of an image not due to atmospheric refraction may mean the centers of the elements are offset—one lens has slid sideways with respect to the other lens. A strong case of all these problems may influence someone to consider basket weaving as a hobby (or career), but then, think of how easy collimating a mirror got to be after you learned the adjustments.

What are the faults of the system? The design, the tube length, the mounting, the work, the lack of information out on refractors. The Littrow design is poor for a short scope, which means a longer tube that is heavier and catches more wind. This in turn requires a more massive mounting unless you have more cash, tools, and better materials, which would save a lot of work.

The lack of information will surely disturb anyone wanting assurance as the work progresses. So why do it? Several times with Herschelians, my friend Jim Axness's homemade 6-inch f/15, and my own 6-inch f/21, I set out to find something and ended up rolling around the sky for the fun of it. Always I was amazed at the pinpoints of starlight and dark background. Image quality. I think the physics of the scope setup makes it a good system. Do it for the thrill of it.

I'd like to thank my wife for her patience and help. Also my kids. I'd also like to thank Mr. Kundrat, Professor Lindblad of Dana College, Norm Remer, David Cartwright, Roland Christen, Jim Axness, and James Daley for their support, advice, and encouragement along the way.

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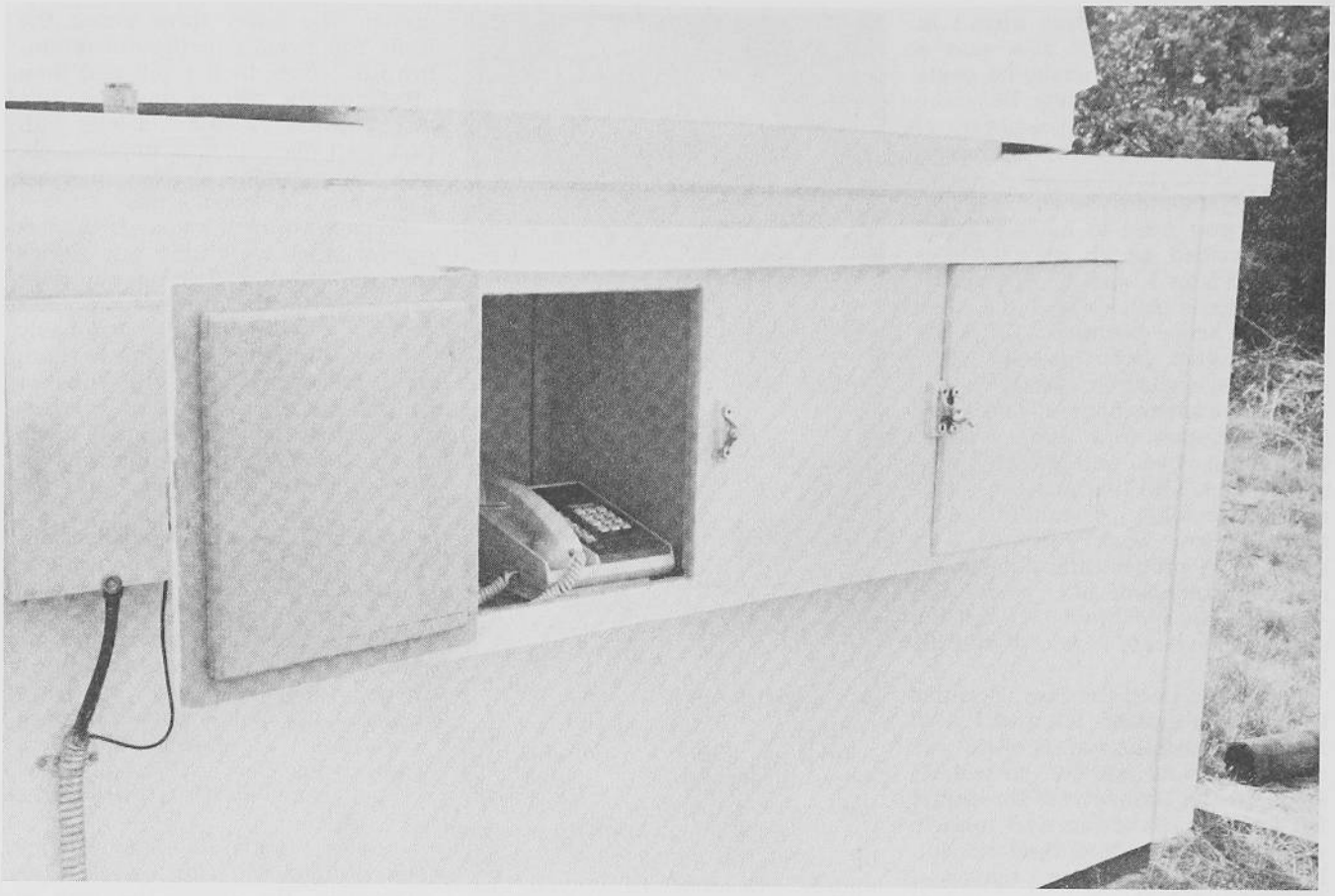

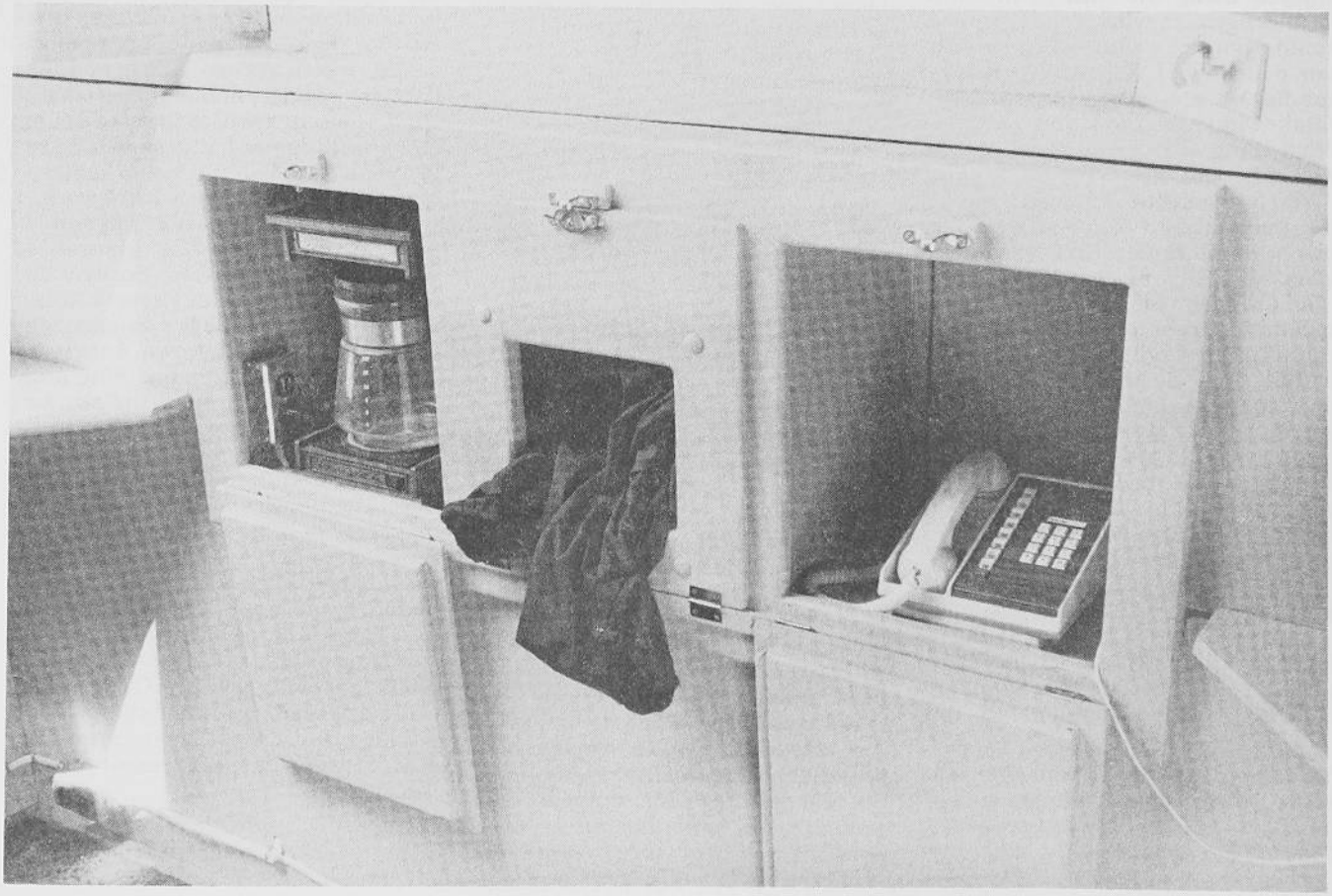

Convenient Cabinets Help a Crowded Observatory

Several years ago I built my own observatory. It provided me with a permanent setup for my Schmidt camera, away from the great cosmic enemy, Big City Lights. The observatory has a common design, an 8-foot by 8-foot square wood frame building topped by a rotating 3-meter dome. I installed storage shelves at the four corners inside the building to hold the usual things that pile up when the observatory is in operation.

After a few months, it became apparent that some improvement in the way things were placed inside the observatory was necessary. The telephone, for example, was always in the wrong place. The triangular shelves in the corners were too small to use a photographic changing bag effectively, and worst of all, the coffee pot was steaming up the inside of the observatory.

Looking at the wide, blank walls of the observatory made me wish there were cabinets mounted flush with the inner walls. However, because the walls are only 4.5 inches thick (3/8-inch plywood on both sides of a 2x4-inch stud), there was too little depth to recess adequate cabinets.

Top: From the outside, the cabinets are a minor protrusion on the east wall of the observatory. The telephone is in the left cabinet, while the coffeemaker is in the right. A small overhang keeps water from trickling around the doors. Bottom: Inside the observatory, elastic cuffed sleeves hang from the door of the middle mini-darkroom cabinet.

Then it struck me: nowhere is it written in stone that the outer walls of the building have to be flat and smooth. Cabinets on the inner wall could protrude as a bulge on the outer wall.

Therefore, I constructed a three compartment cabinet. I inserted the entire unit into a cutout in the east wall of the observatory. Each of the three separate doors open down, so they do not protrude into an already crowded observatory.

The cabinet assembly and the two divisions separating the three compartments were made of 3/4-inch plywood, thus they could take the load previously supported by the wall studs that were cut to allow installation of the cabinet assembly. The part of the cabinet protruding outside the building was weatherproofed with caulking and tin flashing.

The left side of the cabinet now holds my coffee maker and the right side houses the telephone. I turned the center section into a mini-darkroom with the addition of elastic-cuffed fabric arm sleeves, similar to a photographic changing bag. The sleeves protrude from cutouts in the cabinet door.

To prevent steam from entering and causing problems with the hypered Tech Pan 2415 film handled in this area, the coffee maker section is sealed off and vented. Two rows of vent holes drilled at the top and bottom of the coffee maker compartment allow the exchange of air. Steam from the coffee maker escapes from these holes to the outside. A small overhang prevents rain from entering.

The coffee and phone sections also have doors that open from the outside of the observatory to allow access to these conveniences while outside the building. Latches on the inner doors prevent unauthorized entry into the observatory through the coffee or phone cabinets. A small overhang shelters the outer doors from rain trickling in past the seams.

These recessed cabinets have worked so well that I am planning another set for the opposite wall. These cabinets will house such observing niceties as a stereo and a place for midnight snacks.

I recommend this storage cabinet setup for anyone who has an almost-too-small personal observatory. The recessed cabinets make the night's observing session more efficient and more productive. The convenience and added space are well worth the effort.

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Toward a Dream:
Constructing the W. J. Nichols Observatory

I'm not sure whether I built my observatory out of the love of astronomy or the need for independence. Although my wife and I belong to the Milwaukee Astronomical Society, good telescope time was sometimes difficult to get, let alone the long drive to the observatory.

In any case, soon after we joined the astronomical society we started looking for property to build an observatory and a future home on. Our friends used to kid us about going out after dark to look for land.

We wanted to obtain four things with our new site. Most important was clarity of the skies and a good skyline, which meant a rural farm-type area. Second, the area had to be away from any city or large subdivisions. It seems funny, almost every time a person from the city moves to the country, they put up a yard light.

We also wanted an area that had little chance of being developed into new subdivisions or industrial parks. Fourth, because we were moving so far from the city where we worked, we wanted to have good access roads to the freeway. At the time it seemed like too much to ask, but after two years of looking we finally found the perfect site.

Then the problems started. Because of certain ordinances in the town, property owners cannot build anything on their property until the primary building has first been built. So we had to file for a special permit to build the observatory first. After a few months of haggling and promising that we were definitely planning to build a home on the same site, we received our permit. It read "permit for storage shed and tower." I wondered about that; maybe they knew something that I didn't.

I had to convince my wife that giving up our annual fishing trip to Canada and working almost every weekend for the next three years would be a "good idea." We finally began construction on the first of July 1984. Because I work for a local construction company, we had a lot of access to all types of equipment that would be helpful. My observatory was going to be a two-story structure. When we started digging out our footings, we decided to dig the entire hole to make it easier to lay out the footings and later to put up the block.

Putting In the Foundation

We started with a 22-foot square hole 4 foot deep. After we set up the forms and poured footings, we started putting up block. We purchased the half-height block from a friend for $25 and a case of beer. We had to haul all the water needed for mixing the concrete in five-gallon buckets from a creek two miles away. We mixed all the concrete by hand with a hoe in a homemade trough. It took us quite a few weekends to complete the fourteen tiers needed to achieve the required height.

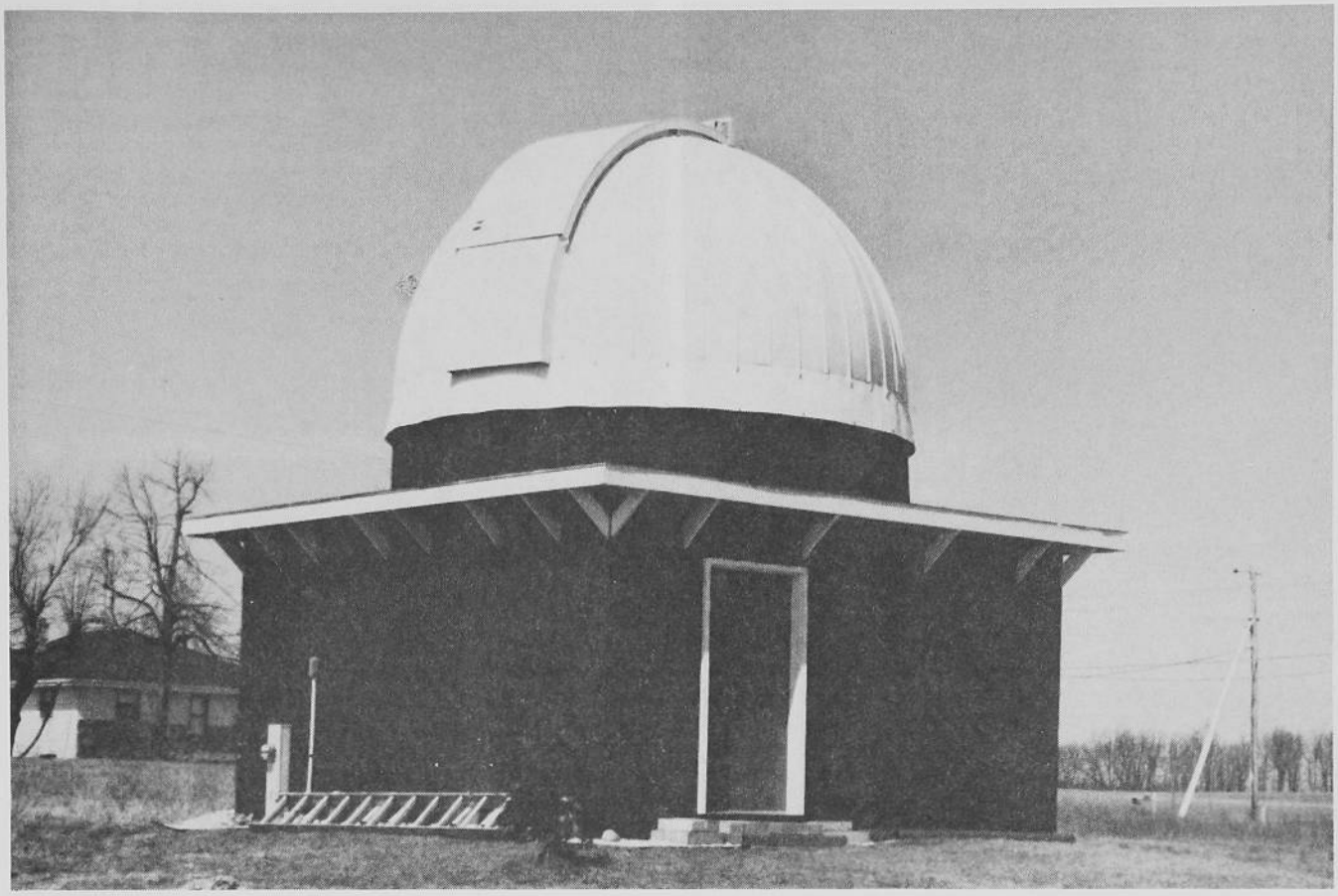
When the last tier of block was finished, I purchased sixteen 1/2-inch bolts each 12 inches long. I used these to secure the 2x6 floor joists to the tops of the blocks, four bolts on each of the four sides. I inserted these bolts into the holes of the block, which were in turn filled with concrete. Because I used 2x6s throughout the structure, I had to build an extra block wall just off center to help support the 20-foot span.

I then bought a 14-inch-diameter, 20-foot-long Sonotube to cast the pier that was to support the telescope. We remeasured inside the block walls to find the exact center point. Using a backhoe I dug down about 10 feet and inserted the Sonotube. Gently we backfilled the hole about one-third of the way, just enough to hold it straight.

Then we used dirt to form up a collar around the tube about 3 feet in diameter and poured in concrete. When we finished, we had a collar about 3 feet around and 5 feet high. After that we finished backfilling the entire hole, leaving it about a foot below the foundation in order to make it easier to finish the first deck.

The First Floor

Because the span of the first floor deck was 20 feet, I decided to put the 2x6s on 10-inch centers to make the structure solid. I used a



From ground-breaking to completion, the observatory took nearly four years to finish. Lower level serves as darkroom, chartroom, and storage.

1/2-inch particleboard for flooring, because it's a lot cheaper than plywood.

For clearance around the pier, we cut a 16-inch diameter hole in the center of a 4x8 sheet and lowered it down over the top of the Sonotube, which left about a 1-inch clearance all the way around the pier. After that we finished laying the rest of the floor.

Once the first floor was finished, we filled the Sonotube to the top with concrete by carrying the concrete in a five-gallon bucket up an 8-foot ladder and pouring it inside the tube. We added 8-foot lengths of 1/2-inch reinforcing rod periodically as we filled the Sonotube. When you cast a pier, be careful that you don't make the concrete mixture too wet, as this can cause the tube to become saturated and collapse.

The last step in casting the pier was to insert three rods made of 1-inch bolts each 12 inches long welded to a 5-foot-long reinforcing rod the same diameter as the bolts. I put these into the top of the tube after the last of the concrete had been poured. These would be used to bolt down the telescope mount to the pier. The rods were sunk leaving 2 inches of thread showing and arranged, by using a compass, so that one of them was facing true north.

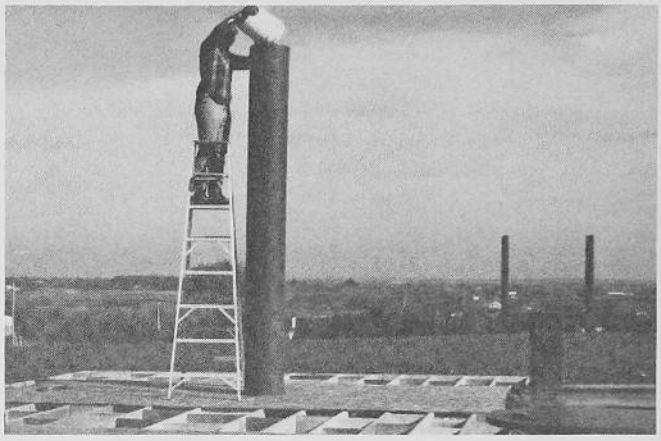
Walls and a Second Floor

We started with the walls next. We used 2x6s spaced 16 inches on center and covered them with 1/2-inch particleboard. As we didn't have any windows and only one 42-inch door, construction was quite fast. Because it was now late fall, as soon as the particleboard was on we made a mad scramble to get everything covered with at least one coat of paint. More than once, as we drove home, we said a prayer that the paint would dry before it froze. As winter was coming on and we were out of money anyway, we used an old pool cover to cover the building as best we could for the winter.

I am a construction worker, therefore, work in the winter months is normally slow. This gave me a lot of time to call around and make price checks on the materials that I would need for the coming spring. I was anxious to start working on the building again. By mid-March, I was into the first project and out purchasing more 2x6s and 1/2-inch particleboard to complete the upper floor.

The span again was 20 feet, so I nailed four 2x6s together to make a solid beam to help support the second floor. To support the beam ends, I cut a 12-inch-diameter base pad out of 1/4-inch flat steel and welded it to a 4-inch-diameter steel pipe, just tacking it in a few places where the pipe meets the pad. (If you weld it all the way around, you will cause it to warp.) For the top support bracket, we made a U-shaped structure like a football goal post, which was just big enough to fit the width of the 2x6s. I needed one of these posts for each end. It worked very well, making a solid beam. As we had done on the first floor, we nailed the 2x6 joists on 10-inch centers.

We had to box in two openings in the second floor. One opening was 16 inches square, and around the Sonotube that protruded about 30 inches above the second floor. The other opening was 2.5 feet wide and 5 feet long for a hatch door. It was somewhat smaller than I wanted,



but we were quite limited with space because my dome was going to be only 16 feet in diameter.

Using the 1/2-inch particleboard, we finished nailing down the second floor. We made sure that none of the flooring would touch the pier, because when the wind blows or when you walk around inside the building, it vibrates your telescope.

The Dome Track

Now I was ready for my track. I decided to use 6-inch channel iron because of the dome's size. Depending on what design you may have for your rollers, you might get by with something smaller, say 4-inch channel. It depends on what you want. The steel was bent in a 16-foot outside diameter. Because of the weight and portability consideration, I had the channel fabricated in four equal pieces and had the ends saw-cut.

On the second floor of the building we placed the pieces end to end, and I had one of my welders weld them together. Of all the things that you do when you build an observatory, this is by far the most important. Take your time and make sure that you have a very level work area. Double-check your measurements so that your circle remains true. Don't weld too much in one place at one time, because this will cause warpage.

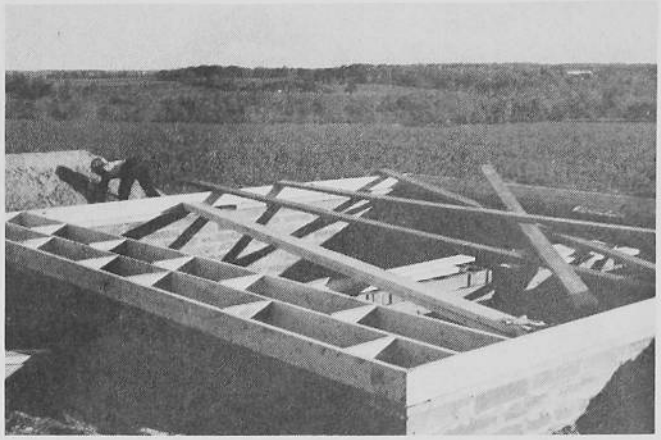
Next we were ready for the wooden structure that holds up the track and dome. We moved the track around so that the pier was perfectly centered inside the circle thus centering the track perfectly on top of the square second floor. Using the track as a guide, we outlined the shape of the track on the floor with spray paint. Thus we had a permanent mark to use as a guide for the supports. The circumference was about 52 feet.

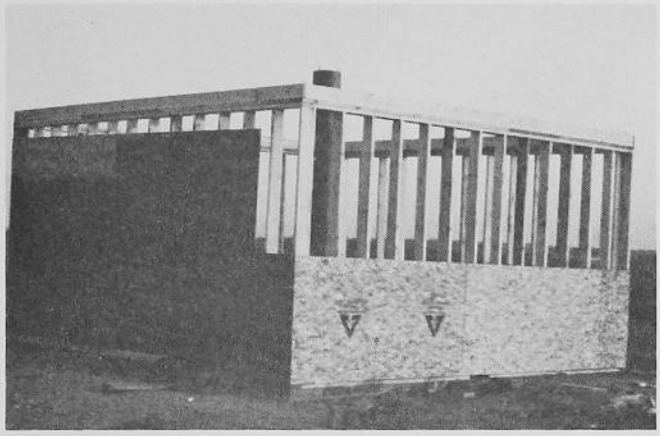
I marked thirteen support locations, one every 4 feet. Each support was made out of two 2x10s about 46 inches long spaced 12 inches apart. I sawed holes through the floor just big enough to insert the 2x10s and dropped them to a depth of 6 inches, so they could be nailed to the 2x6s under the floor. Several cross pieces were then nailed between and on top of the 2x10s which formed a boxlike structure that was very secure.

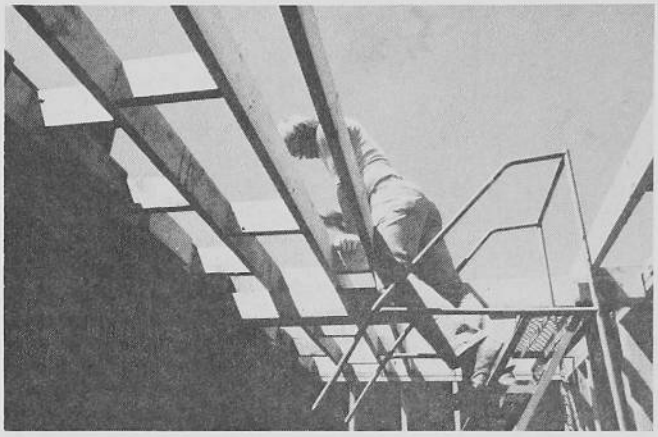
Now came the track guides and rollers. The track support assemblies sit on top of each of the thirteen 2x10 pedestals. The bottom plate is made out of 1/4-inch flat steel 6 inches wide and 10 inches long. Four slots, each about 3 inches long, were cut in the plate so the assemblies could be adjusted to conform with the inner curvature of the track. Each assembly plate was bolted down to the support mount with four 3/8-inch bolts. The actual rollers were taken from a small commercial conveyor belt.

I used three rollers on each pedestal to conform with the curvature of the 6-inch channel iron. One rolled inside the top lip, another inside the bottom lip, and a third rolled face-on the middle of the channel. This way the track rolled smoothly. The rollers are made of stainless steel. They make somewhat more noise than rubber ones, but it isn't that bad.

Next, we framed the circular second floor structure by closing in our thirteen 2x10 track supports. For this we purchased several sheets of 1/4-inch particleboard; we needed it that thin because it was easier to make the bends. (We originally had tried 1/2 inch but it was almost impossible to bend to our radius.) When nailing the particleboard to the outside of the supports, we found that roofing nails worked best. They have a large head and







Rising from a hole in the ground, the first floor 20-foot square building went up the first year. The 14-inch pier is filled with concrete.

will not rip through the thin board. If you build an observatory, you may find that adding a few support columns between the others will make it easier and will save on wasted particleboard and cost.

After we completed the first circular wall, we added a second wall over it, again using 1/4-inch particleboard. This time we overlapped each seam simply by starting between panels and going around from there. We used 1-inch screws, like those drywallers use, instead of roofing nails. The screws drew the two walls together tightly. We finished this project by painting the particleboard to help preserve the wood.

Meanwhile, we set the steel door to the building in place. It was easy to install, because it came preassembled, the only work involved was to nail it to the 2x6 framed opening. That same day we finally had electrical service installed by the electric company. A few days later I had an electrical contractor come out and hook up my service. It certainly was nice not to have to take a generator out with us every time we wanted to work on the building.

Putting a Silo On Top

Now I was finally ready for a dome. During the past winter I had called several farm implement dealers for price checks on silo-top domes and struck a deal with a dealer in Lake Mills, Wisconsin. (There are several farm silo dealers in that area.) So one Saturday my wife and I drove over and picked up the 16-foot dome. It came in twenty-five pie-shaped panels. Each one weighed 30 pounds and was 7.5 feet long.

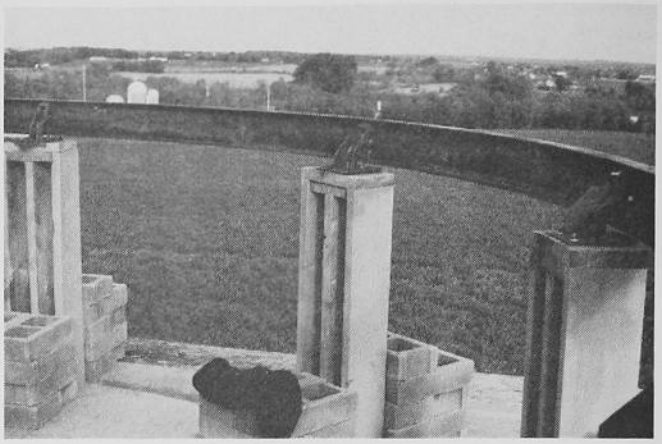
The next day we put it together. I had made arrangements with a couple of friends to come over after church and help assemble the dome. I think that Sunday turned out to be the worst day of the year -- windy and cold -- but I was too anxious to stop.

Each of the silo panels has a small anchor hook riveted to the center of the sheet. It was easy to start putting up the dome. I just drilled a 3/8-inch hole in the center of the 6-inch channel iron on the track, then bolted the panel down. Because each sheet is tongue-and-grooved, when you slide them together they interlock. After you have three or four panels put up, a circular hoop with predrilled holes attaches to the top of the dome to help secure it better. This hoop also serves as a guide for the rest of the panels.

The wind tried to rip each new panel out of our hands or send us hang gliding off the ladder. As soon as we had a half dozen panels up, we turned the dome into the wind. This made the panels a lot easier to handle.

Before we installed the last few sheets, we had to get 2-inch angle irons inside the dome. These would be used to hold the dome together and to construct the shutter and hatch door. Once the angle irons had been hauled in, we finished putting up the last panels. The entire job only took about four hours.

Our last project, before cold weather ended progress, was to tarpaper and shingle the roof and round sides on the top of the building. The sloped roof area went on fine, but the round-sided walls gave us trouble. Remember that we had used two thicknesses of 1/4-inch



particleboard? Well, when we started nailing the shingles on, it was hard to pound the nails into the thin board, so we had to use a lot more nails. Because that part of the building is vertical, we also had to use roofing cement to hold the shingles down or the wind would blow them off. It took a long time to finish, but it worked very well.

Thus ended the second year.

Cutting the Dome Slot

The following spring we started working on the shutter and hatchway openings. The 26-foot length of angle iron which we had put inside the building last fall measured 2 by 2.19 inches and was bent to an outside diameter of 16 feet. First we found the center point at the top of the dome, then measured and marked two points an equal distance (21 inches) on either side of it. We drilled several small holes in the 2-inch irons and cut several 42-inch 2x4s.

We set the 2-inch angle irons on top of the 6-inch channel iron, nailed some 2x4s as spacers, and tacked one end of the irons to the 6-inch channel. Maintaining our 42-inch shutter door width, we cut off the few extra inches of angle iron and welded the irons in place. When you are marking the 2-inch angle irons before cutting, make sure you push them up against the top and insides of the dome firmly. Also have someone check that you are making contact all the way around. You will find that you may need several people to help hold everything in place. Remember never to weld too much in one place at one time, or the metal will warp.

Using our Master Craftsman plumb line (a string with a large nut tied to the end of it), we confirmed that the center of the dome was directly above the center of the telescope mount. We marked a point at the top of the dome 10 inches beyond center. I wanted to make sure that I could point the telescope straight up through the hatch and not have any dead spots. We took a piece of 1/4-inch-thick flat steel 2 inches wide and 42 inches long and welded it to the 2-inch angle iron on both sides at this marked point.

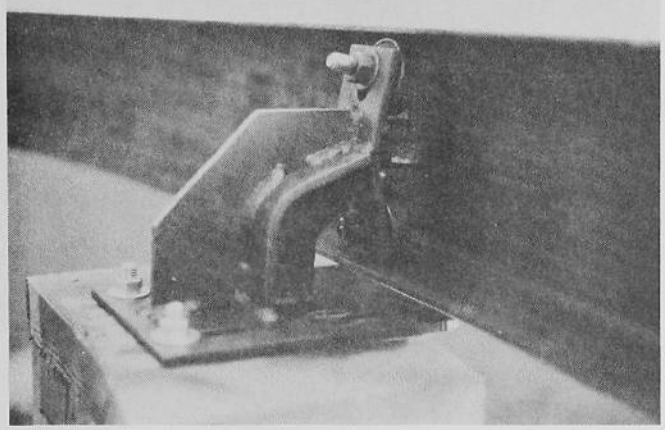
Next we replaced the 42-inch wooden spacers on the back side of the irons, opposite the proposed hatchway door, with pieces of flat steel, evenly spaced and welded. Make sure you leave the 2x4s on the front side in place.

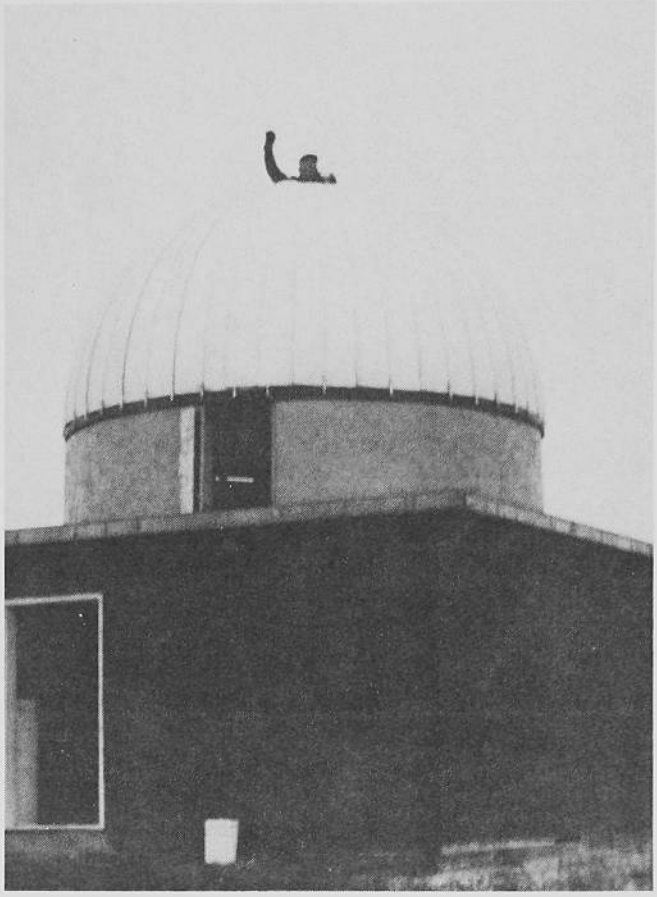
Cutting out the shutter and hatchway openings came next. I used a magic marker to outline the entire inside edge of the 2-inch angle iron where the opening was going to be. The panels slide when you release the bolts where the panel attaches to the 6-inch channel iron and at the top of the dome where they attach to the round hoop.

When you start taking out the panels begin at the top because the panels are pie-shaped and smaller at the top. You can lower a few panels at a time. When you cut the panels, mark the edge line 1/2 inch back from the opening. This allows room for the 1/4-inch by 6-inch flat steel that will later be welded to the edge of the 2-inch angle iron.

After you have re-marked and removed the panels, cut them using a jigsaw with a metal cutting blade or a grinder with a cutting disk. Both methods work fine. Slide the panels back in place and rebolt the bottom to the 6-inch channel iron. Panels at the top of the dome will no longer be attached to the circle. You will have to start drilling holes in the 2-inch angle iron and attaching the panels to it.

We used 1/8-inch bolts about 1 inch long and spaced them a few





The rotating ring is a 6-inch rolled-steel channel suspended on thirteen sets of rollers. Aluminum silo parts were used to construct the dome.

inches apart. I also inserted a rubber washer along with a flat washer on the outside of the dome and just a lock washer on the inside. We couldn't find inexpensive rubber washers to buy anywhere, so we made our own by cutting circular pieces from a rubber inner tube with scissors and punching out the centers. We used a few hundred bolts and washers before we finished. With all the drilling, our arms were relieved when we finished.

Ladders and Stairs

While we worked on the observatory, I used a stepladder to get to the second floor. It was alright going up but not too safe coming down. During a lull, while I waited for more steel to be bent, I decided to catch up on a few neglected projects.

For the staircase I used two 2x10s about 10 feet long and spaced them 32 inches apart. The ends were cut off both boards on angles to adapt to the floor and opening at the top, where I had previously boxed in the hatch door opening. When you do this, make sure that you leave enough room so that the hatch door can close flush with the upper floor.

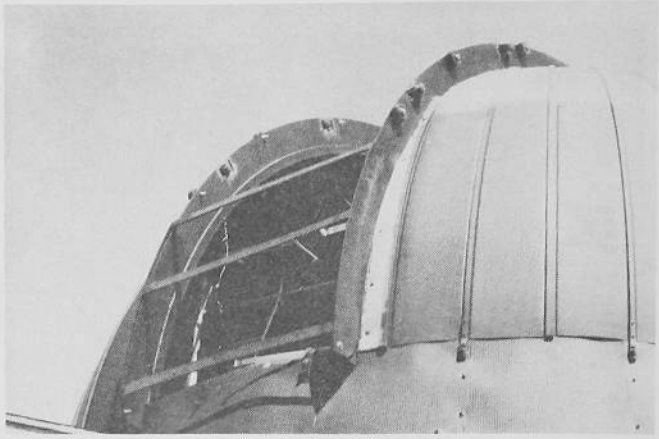
I made the treads from 2x10 boards, evenly spaced. For added support I cut pieces of 2-inch angle iron and bolted them to the edge of each tread and the stair casing.

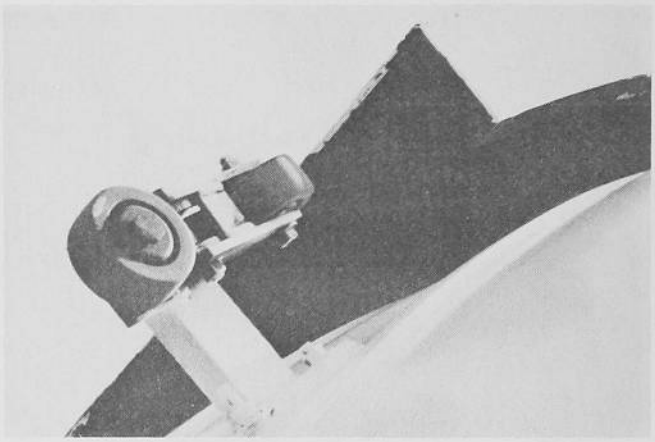
Next I started work on the hatch door. For this I used two thicknesses of 1/2-inch particleboard fastened together with small gripper screws. I installed a 1-inch square molding board all the way around the hatch opening so that the door would fit down flush with the floor. I attached three small hinges and two small handles. It made a very nice door.

Another project proved a little more challenging: trying to find something that we could use for the flashing around the dome. Believe it or not, we finally ended up using an aluminum swimming pool liner. It was about 1/16 inch thick and very flexible. I needed something to hold the flashing securely and slightly away from the dome so that the rainwater would run off. I used thin strips of soft steel 18 inches long, 1.5 inches wide, and 1/8 inch thick that bent easily. In each one I drilled a 3/8-inch hole. You will need twenty-five strips in all; this matches the number of pie-shaped panels on your dome. I bent each strip about 4 inches down from the top so that it would curve out away from the dome.

With a jigsaw I cut the aluminum pool liner into twenty-five rectangular pieces each 20 by 27 inches. I went around the dome putting on my 18-inch-long steel strips with the same bolts that held the pie-shaped panels to the 6-inch channel iron, and then put the flashing panels on them. I pushed each piece up under the dome roof about 2 inches. I drilled a hole in the panel from inside the dome using the same hole from which I had removed the 3/8-inch bolt, then reinserted the bolt.

You need two people for this job: one to drill and one to hold the panel and steel strips in place. Once a few of the panels are on, it becomes easier. You could use small bolts or pop rivets to attach the panels to the strips of steel. I used two bolts on each panel. It took one whole day to complete this project.





Slot and Shutter

Toward the end of that week I received word that my steel was ready, so I could get started again on my hatch opening. This was to be welded to the edge of the 2-inch angle iron to form a shutter opening. Each sheet was 1/4 thick by 6 inches wide, with an inside diameter of 7 feet 9.75 inches.

Remember we cut the panels back about 1/2 inch shorter than the original marks back when we put the roof back on? Now you know why! We needed this space to weld the 1/4-by-6-inch flat steel in place. When I had the steel bent, I again ordered 52 feet. You will need the extra length for the hatch door that drops down.

When the steel was bent I had it cut in four equal pieces each 13 feet long. The actual shutter and hatch door opening was roughly 14.5 feet long. You'll have to do some extra cutting and filling in to complete the radius on each side.

We added an extra 6 inches when we measured the opening so that the flat steel extends to the bottom of the 6-inch channel iron. You also need the extra room for the hatch door to drop and to keep snow and rain out. There will be a considerable amount of welding needed to complete both sides. Make sure not to do too much welding in one place at one time and make sure that the 2x4s are still in place to maintain required spacing.

With the leftover 6-inch flat steel from the shutter door opening, I started work on the hatch door for the bottom end of the slot opening. This fold-down door was about 36 inches high.

After cutting two equal pieces, I used C clamps to secure each piece to the outside of the 6-inch curved steel, which we had just finished welding. I drilled two 3/8-inch holes, one in each side about 1 inch up and 1 inch in from the front side. Then I inserted a nut, bolt, and washer and tightened them down. I then cut three strips of flat steel 1.5 inches wide and 1/4 inch thick to be evenly spaced and welded to the outer edges of the hatch door.

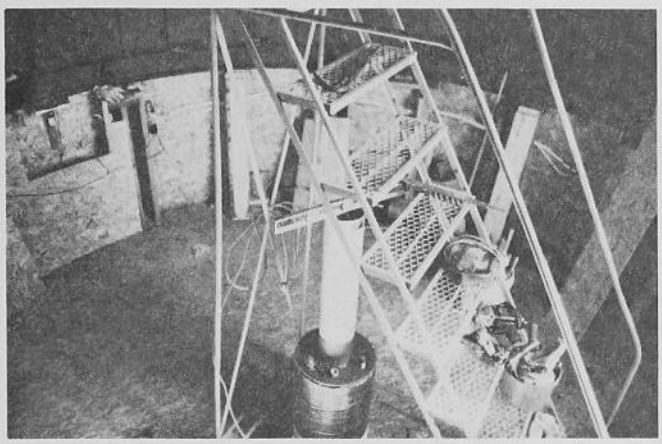
For the actual hatch door I used 16-gauge steel. It was somewhat thicker than I needed, but I had done some bartering and had picked up the two 4x8 sheets quite reasonably.

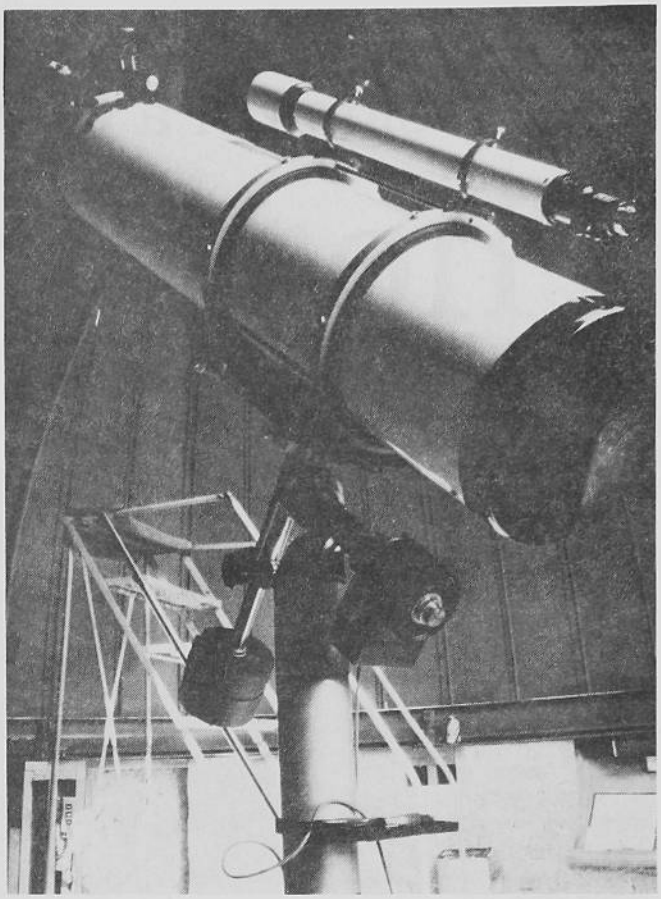
My next project was my shutter door. I used 4-inch channel iron bent to an 8-foot 4.75-inch outside diameter. Two 11-foot-long pieces allow you enough material to overlap the hatch door and still have about 8 inches on the backside, to help keep out rain and snow.

When you measure your opening, you are going to have to add a couple of inches for the rollers. I added about 1.5 inches on each side and it worked fine. Then I cut four pieces of 2-inch-wide strapping material. I spaced them evenly and welded them to the edges of the 4-inch channel.

Make sure you have a level working area when you do this, or you might have problems with pieces not matching up. With the frame made, you can cut and tack the 4x8 sheets of flat steel. These can just be spot welded every few inches. It's a good idea to put a good heavy primer coat of paint on your door at this point. Once you have it in place it becomes very difficult to paint.

Before we could put our shutter door in place I had to install the rollers and casters. For this I used 1.25-inch by 3-inch Rapistan wheels. Made of hard rubber, they have proven to be durable and quiet. I cut four 4-inch-long vertical slits in my 6-inch flat steel about 1





Up-and-over shutter closes the top end of the slit; a fold-down door closes the bottom 3 feet. The observatory houses a 12-inch reflector.

inch down from the outer edge. This made the opening just large enough for the rollers to move freely.

On each side I installed four sets of rollers, and drilled four 3/8-inch holes through the flat steel at points evenly placed between the vertical slots, about 1/2 inch in from the outer edge. I attached vertical rollers at these points also; these serve to hold the shutter door in a centered position. The other wheels support the weight of the shutter door. You might have to make a few minor adjustments so everything fits firmly into the 4-inch channel on the door.

Now, if you have enough help, you can put the shutter door on. Because we had already installed the rollers on the front side of the opening, we had to slide the shutter door on from the back side of the dome.

Once we had the shutter door in place, I made brackets and roller supports to hold the door in place when it was fully rolled back and open. We made six brackets, three on each side, about 2 feet apart. I used 2-inch angle iron and 1/4-inch flat steel for them. We designed the back rollers to fit inside the 4-inch channel, both vertically and horizontally, so that when the shutter was rolled back it is held very firmly. Once again I used 1.25-inch by 3-inch Rapistan rollers.

Finishing Touches

I spent a lot of time thinking about exactly how I wanted to open the shutter. There are probably as many different kinds of door openers as there are observatories. I decided on a gear and chain combination with a large chain in the center of the shutter door.

The chain is about three times as large as those on bicycles and extends the length of the shutter door. We spot welded the chain in place using small shims under the chain. When the door is opened, the gear penetrates all the way down into the chain.

We purchased a 1/2-HP electric motor, a 60:1 gear reduction box, a 3/4-inch solid shaft, three gears of the same size, and two 3/4-inch pillow bearings. I mounted the motor and gear box on a piece of 1/4-inch flat steel. I used two pieces of 4-inch channel iron 4 inches long to bolt the pillow bearings to.

When we got the power hooked up to the motor, I was just a little suspicious of whether everything was going to work properly. Like everything else in the construction of the observatory, we built the shutter drive on a more or less trial-and-error basis. But everything worked beautifully—the shutter rolled over the dome smoothly.

After three-and-a-half years and thousands of hours of work, for the most part our dream observatory is finished. There's still a lot of cosmetic work to do. The dome needs a second coat of white enamel paint, and there is paneling and wiring work still to do on both floors.

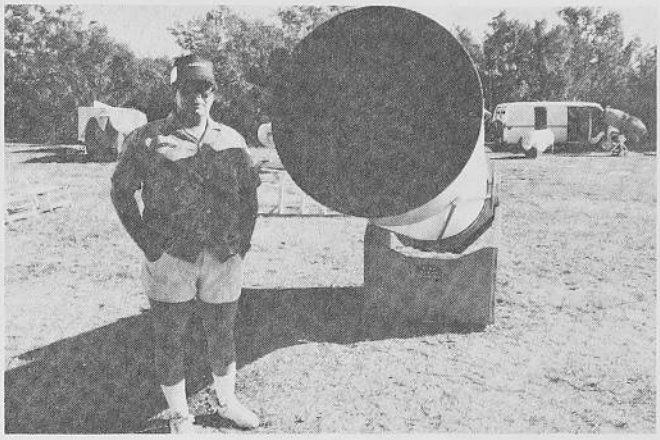
However, the observatory is operational and makes a fine home for our Meade 12.5-inch Deep Space Research Series Newtonian telescope. We received first light on Christmas morning in 1987, sighting in on a barn and farm silo a few miles away. Needless to say, I couldn't wait for night to fall.

"Nick" Nichols
3885 Pioneer Road
Richfield, WI 53076

Confessions of a Convert:

The Winter St★r

Superb seeing, dark skies, and lots of large telescopes made the Winter Star



Never again will I suggest to anyone that mountain sites are best for astronomy. Never again will I underestimate the importance of good seeing. Never again will I question the value of first-rate optics in big telescopes. Never again...

I'll tell you why I've made these resolutions in this story, and what we all stand to learn from a phenomenal site in the Florida Keys. Just as a decade ago the skies of Texas and California opened the eyes of this East Coast native to the paramount importance of sky blackness, this winter my eyes were opened to the merits of steady seeing and uniform air.

I suspect it's something you will have to experience before you'll believe me, and it's something that the natives don't seem to fully appreciate. Let me conclude this prelude and begin the story again in the conventional journalistic formula:

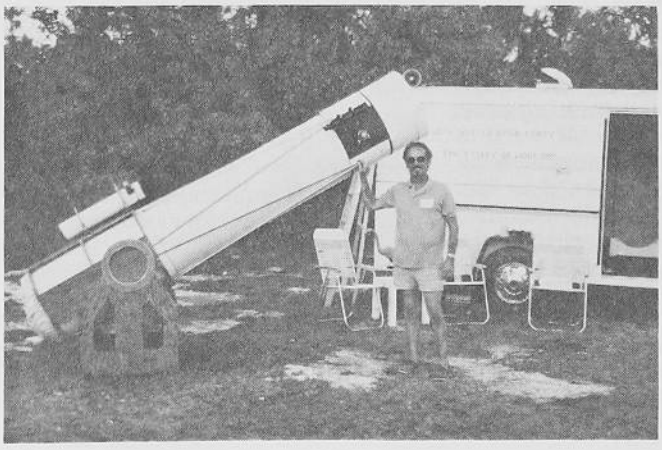
Four clear nights graced the fifth annual Winter Star Party on February 2-5, 1989. Sponsored by the Southern Cross Astronomical Society of Miami, the Star Party this year attracted 320 amateur astronomers to Camp Sawyer on Spanish Harbor Key in the Florida Keys.

Camp Sawyer is a Boy Scout camp with sites for tents and rough-it-style facilities suitable for hordes of small boys. It's located about two-thirds of the way between Key Largo near Miami and Key West, right at the "kink" in the line of the Keys. Twenty miles east of Camp Sawyer is the streetlighted city of Marathon; forty miles west is the brilliant tourist mecca Key West. Havana lies 100 miles distant, a faint glow on the southern horizon.

The primary activity at the star party was deep-sky observing. There were over 130 telescopes at the site, including a 25-inch Dobsonian, four 20-inch telescopes, one 18-incher, and at least half-a-dozen 17.5-inchers—not to mention several dozen in the 10- to 16-inch range. The large number of altazimuth telescopes prompted the observers to nickname the aperture-filled field beside star-party chairman Tippy D'Auria's trailer the "Valley of the Dobs." More about this later.

Ele and I arrived at the Camp Sawyer late Thursday afternoon. We spent the morning driving down from Homestead (our base of operations for exploring Everglades National Park), and the early afternoon on a glass-bottom boat bobbing over the reefs in John Pennekamp Coral Reef State Park.

We registered quickly and hurried to find a sheltered spot to set up our little tent. Try as we might, we couldn't find deep dirt to pound tent stakes into. The ground, although smooth, is even more tent-resistant than Stellafane! As darkness fell and the first stars popped into view, we chucked our sleeping bags and suitcases into the tent.



The sky we saw was incredible. In the west, the tall, thin cone of the zodiacal light

P★rty

an unforgettable experience.

Aperture fever. Tom Clark with his 25-inch Dobsonian. Tippy D'Auria and his diffraction-limited 18-incher. Steady air. Dark skies. Perfect night vision. Warm breezes. Cause for aperture envy, seeing envy.

extended perhaps 40 degrees high. The Milky Way arched high overhead, flowed past high-in-the-sky Orion, tumbled through Canis Major, and gurgled into the horizon behind the rising stern of Argo Navis. Jupiter hung at the zenith. Sirius gleamed on high; rival Canopus hung low over the Straits of Florida.

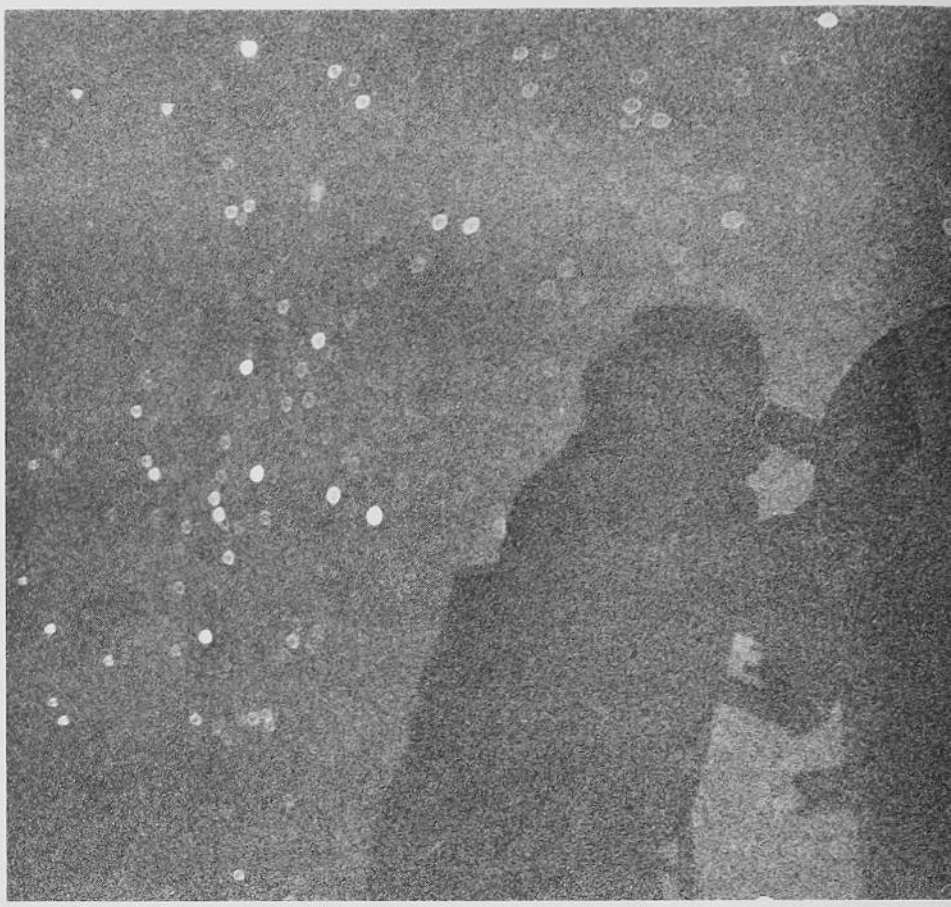
The sky was not perfect. Low in the west, the 10-degree glow from Key West and developments on Big Pine Key lit the sky. To the east the city glow of Marathon lit the air. Bright lights mounted on high poles lit the Girl Scout camp next to Camp Sawyer—these little girls would not see the stars—but canvas shields and vegetation blocked the worst of the glare from our view. But overhead the sky was translucent pearly gray to our eyes, and filled with bright, untwinkling stars.

An outstanding quality of the WSP was tight control of on-site lights. After dark, star-party rules prohibit white lights of any kind. This allowed our eyes to become fully dark adapted. Although the RTMC and Stellafane also have "no lights" policies, the rules are often ignored. My eyes became profoundly dark adapted.

That first night we stayed up until the wee hours, wandering from telescope to telescope looking at whatever sights people offered. Ele and I walked over to the shore and gazed across the water. We took the night photographs that appear with this story. (I want to say "thank you" to the photographer who lent me his tripod and even took some of the pictures for me. I never got his name.)

I chatted for hours with people whose faces I never saw and studied the Orion Nebula in a dozen different telescopes (Ele didn't understand this), while I carefully checked out optical systems and collimation. Under the steady Florida skies, the nebula was beyond description. The fifth and sixth stars in the Trapezium—tough objects where the seeing is poor—were bright and obvious. The nebula itself, showing the palest tints of red and green, was breathtakingly detailed at 600x.

More than anything, the seeing at Camp Sawyer impressed me. Not even in Jeannie and Tom Clark's



25-inch f/5, for example, did the star image dissolve in turbulence. Racking a bright star out of focus would show figure and collimation, slow currents moving in the tube, but only the gentlest shimmer of moving air outside the tube.

I was amazed. The breeze coming off the ocean never stopped, and I generally associate moving air with turbulence. Of course, on the Keys that air has flowed over hundreds of miles of isothermal sea, not Wisconsin's cool woods and warm fields, Riverside's sun-baked mountains, or around the hills and valleys at Stellafane. I never saw star images bigger than one arcsecond, and they were usually much smaller.

The next day, Ele and I drove to Bahia Honda State Recreation Area, an unspoiled key with beautiful white coral sand beaches, walking trails, a store, and marina and picnic areas. We waded in the delightfully warm water (75F!), lunched, walked the stub of the old bridge, and read for hours beside the nature trail while little lizards came to stare at us. It was a relaxing day—I only wish we'd also taken a nap. By nightfall, I was already sleepy.

But that night, Friday night, was the best of all. In a variety of telescopes, I saw the Horsehead Nebula. Through an H-Beta filter at 400x, the outline and detail in the dark nebula were visible. Through a diffraction-limited 20-inch reflector, I saw the central star in the Ghost of Jupiter easily. The CBS-logo shape stood out clearly and crisply against the circular component of the nebula.

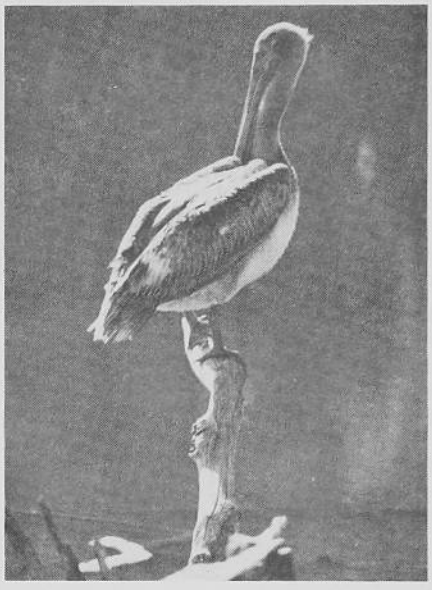
I have seen Omega Centauri at the TSP, at Riverside, and from Hawaii. Omega often seems to "swim" in the eyepiece, unlike any other globular I've observed. In telescopes from 10-inches to 25-inches aperture, however, the stars shone sharp and untwinkling in vast numbers. It was an awesome sight.

Tom Lorenzin, author of 1000+, went from telescope to telescope pointing out especially interesting but little-known nebulae. On his recommendation, I viewed NGC 1999, a beautiful little nebula south of the Orion Nebula with a dark chevon across the middle. Tom based the list of 1,100 deep-sky objects given in this book on objects he observed and found appealing.

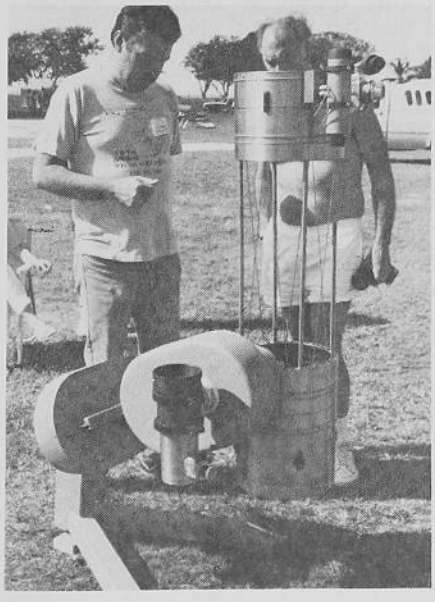
The prize, however, went to Eta Carinae. Skimming just 6 degrees above the horizon and over the ocean haze, this nebula was a show-stopper. In the 25-inch with a deep-sky filter, it seemed as bright as the Orion Nebula. The ruddy star at the core, however, appeared as two objects, one red and one green because of atmospheric dispersion and the Now is the timedouble band pass of the filter.

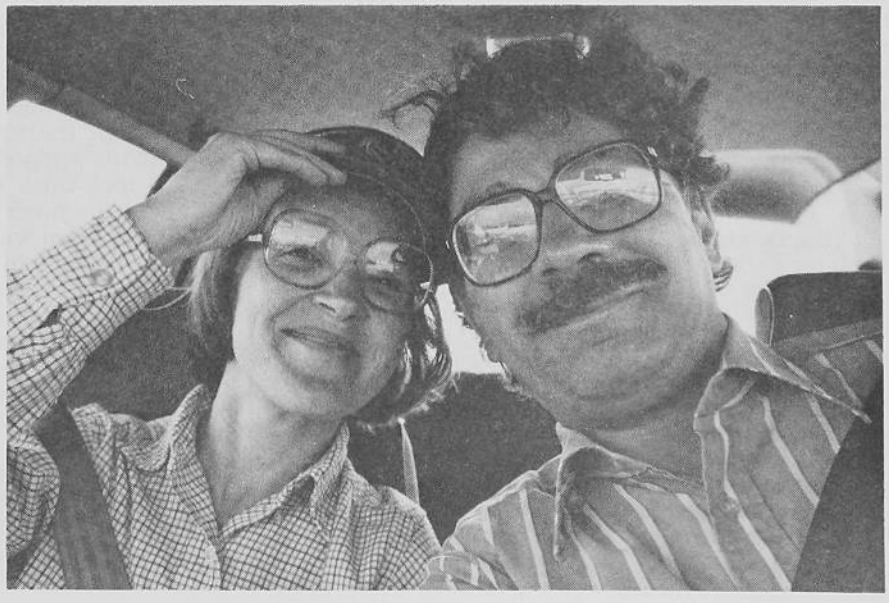
A totally unexpected treat was the Gum Nebula. This nebular region is shown on Uranometria plate 397, but I had never heard of anyone observing it visually before. We swept from knot to bright knot along glowing streamers of gas and down a straight north-south segment. This part is detached and looks for all the world like a jet contrail. I didn't get the name of the observer who showed the Gum in his 20-inch, but thanks!

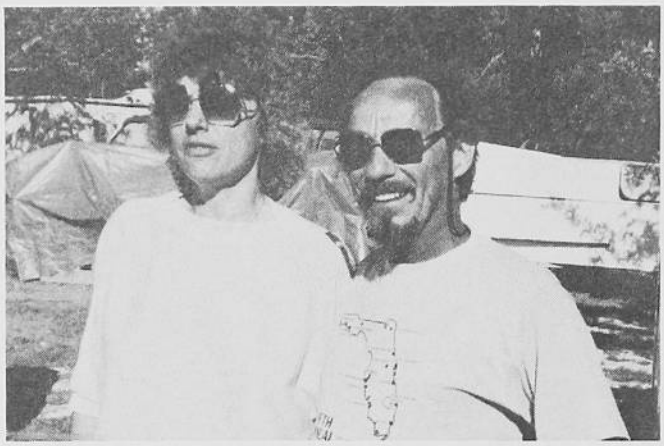
I spent a fair amount of time talking to Tom Clark of Tectron and checking out his 25-incher. Tom is responsible for populating "The Valley of the Dobs" with an assortment of 20-inch Tectron telescopes. (Actually, the 25-incher may "belong" to Jeannie Clark, because it is a replacement of a replacement of a replacement for the original 13-inch Odyssey Tom gave to Jeannie. At any



Clockwise from upper left: Through an H-beta filter in the Clarks' 25-incher, with Sirius over his shoulder, an observer studies the Horsehead Nebula. The telescope field at Camp Sawyer as dark approached: 130 telescopes for 320 participants! Domes and trailers for camping under the trees. A brown pelican preening. (There were also ducks, gulls, terns, grebes, herons, osprey, too.) Ele and Richard on vacation—a self-portrait at 60 miles an hour. Ron Simpson's Radio-Shack-Color-Computer-controlled telescope. Bill Rigby and Bill Williams photographed the magnificent horizon-skimming nebula, Eta Carinae, with a telephoto lens on Tech Pan film.







rate, Jeannie is the observer in the family and Tom is the telescope builder.)

Tom's telescope was of special interest because of its 2-inch-thick mirror, made by Galaxy Optics. This size and thickness push the limits of what amateurs have done. How good is the mirror? What sort of support system does it need? What I observed with Tom's scope is that such a mirror is quite flexible, but capable of superb performance. Sometimes the images were flared or irregular, but at other times they were nearly perfect. Galaxy's mirror was therefore excellent.

Tom's 18-point mirror cell appeared to be well made, and clearly supported the mirror well most of the time. I would guess that sometimes the supports "hang" as they do with my 20-incher and need to get worked free. I never tried to "exercise" the cell when the images looked a bit odd, but I'd guess that a horizon to zenith swing and back from time to time would have kept the support system limber. When my own 20-inch "hangs," I point the 350-pound telescope at the zenith and shake it with all my strength. That usually restores the symmetry of the figure.

I found myself agreeing with Jack Newton's assessment that Tippy and Pat D'Auria's 18-inch was, in Jack's words, "the finest Dob I've ever seen for star images." In this telescope, Jupiter's clouds broke into countless fine detail, and the disks of the satellites were readily visible. Even Mars, only 7 arcseconds diameter, showed surface features. The mirror of the 18-incher was made Ed Beck of Enterprise Optics.

Although the tube of the 18-incher looks solid, it's not. Struts support the upper end, and the "solid" wall is 1/4-inch-thick hot-wire-cut foam rolled into a tube. Many of the other telescopes, including the 25-incher, also had foam-wall tubes. Tippy gets his foam from Diplast Plastics in Miami for $4 per 4-by-8-foot sheet. The tube wall prevents dewing, which everybody said is a problem in southern Florida.

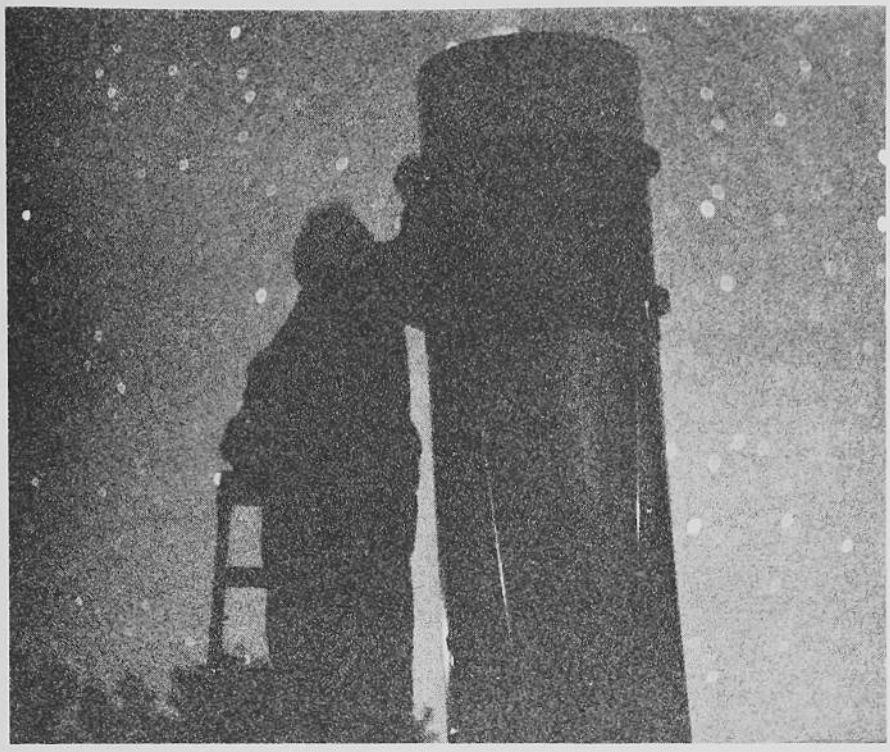
But the thin foam tube wall can spell trouble. The first night Tippy put the new tube into service last year, a cat reportedly jumped into the open end of Tippy's telescope's tube and started walking down toward the mirror. Under its weight, the thin foam cracked and dumped the cat on the ground. Tippy's telescope looked like it had been shelled until he repaired the hole.

Well, everybody at the star party knew about this, so some practical jokers put a stuffed-toy cat into Tippy's

The 23rd Psalm of the Astronomer

The Dob is my Telescope; I shall not want. It maketh me go out on Dark Nights; it leadeth me through the Messier Objects. It restoreth my Night Vision; it leadeth me to Star Parties. Yeah, though I walk through the Valley of the Shadow of Large Telescopes, I will fear no evil, for my Naglers and Widefields, they comfort me. Thou preparest a Star Chart before me in the presence of the Galaxies; Thou annointest my head and optics with Dew; my Eyepiece cloudeth up. Surely Good Seeing and no mosquitos shall follow me all the days of my life, and I will dwell in the Deep Skies of the Night forever.

— David Knowton



Pat and Tippy and Jack and Alice: the D'Aurias and the Newtons. Tom Clark as Narcissus—or perhaps gazing into the future of the large Newtonian? An explanation of sorts for the "Valley of the Dobs," by David Knowlton. Checking out Jupiter's belts and zones in Tippy's foam-tubed 18-incher. Struts gleam under starlight. Starlight photos shot on P3200 pushed to ISO 6400 in T-Max developer, exposed for 10 seconds at f/2.

telescope and then paged him over the speaker system. "Tippy, please go to your telescope. There's a cat in the tube!" Tippy had to brave a chorus of "meows" for the rest of the night.

On Saturday Ele and I drove to Key West. We saw the Audubon House (which belonged to someone else—Audubon only slept there) and looked around the town. Restaurant prices were out of sight and the town was packed. It reminded me of Big Bear City at Riverside: tacky and tourist-hungry. We probably missed the good stuff, but I wasn't much impressed with what we saw.

To last through to the wee hours of Sunday morning, I rolled into the sleeping bag an hour before midnight Saturday, then overslept and woke an hour before dawn. Although the sky was clear, all the telescopes were closed down. Clouds after midnight had sent everyone to bed. Ele got up with me, and we walked down to the edge of the ocean, and watched the summer Milky Way rising out of the zodical light until the dawn swallowed them both.

Through each of the clear nights, every twenty minutes or so we'd hear a prolonged "whoooooosh!" It was a number of astrophotographers and Jack Newton making dry ice using explosive decompression of carbon dioxide from a pressurized cylinder. Jack was showing off his plug-type cold camera and getting good results. Among the photographers, I met Bill Williams, inventor of the Celestron-Williams cold camera, who is now getting back into photography with Bill Rigby. He even remembered a story I wrote for ASTRONOMY years ago, in which I mentioned him and his camera!

In a future issue of TM I hope to run a story about Ron Simpson's computer-controlled telescope. He ties directly into the data bus of a Radio Shack color computer, through the game port, to control a 10-inch equatorial reflector. It looks like a clean project with some solid and original ideas that telescope makers would benefit from.

On Sunday Ele and I drove to the key deer refuge in the morning and visited the laundromat in Big Pine. That night was clear again; there were three large telescopes left and at least a dozen smaller ones, but everyone was tired. When low, fast-moving clouds showed up, everybody seemed to be a bit relieved. Ele and I turned in around midnight and slept like logs.

On Monday morning, Ele and I said our goodbyes and returned to full-time vacationing. We drove across the Tamiami Trail to Everglades City, checked into a small old-timey motel, took long hot showers, brushed our teeth properly, and reveled in feeling clean again. We like camping, but...

From Everglades City we took a boat to the 10,000 Islands, watched dolphins diving, assorted waterbirds nesting and flying, and more mangroves feeding the food chain. Driving toward Fort Myers and Sanibel Island, a fire near the road forced us to detour 60 miles, so we got to see the seemy underside of Fort Myers.

On Sanibel, we spent the day exploring the J. N. "Ding" Darling Wildlife Refuge, a mangrove swamp that occupies about a quarter of the island. The birds there were unafraid; a quiet person could come within a few yards of herons and egrets, cormorants and pelicans, ibis and grebes. It wasn't astrophotography, but the birds are as magnificent as the nebulae in their own way.

The astronomical lessons of the trip include deeper appreciation for super seeing and faultless optics. Never again will I settle for anything less.

Nor will I ever again don my down parka while scoffing at "softies" who observe the Orion Nebula in warm tropical breezes. There's no need to question the quality of sea-level sites. If you live there, you're lucky. Telescope makers and observers in sites with yucko seeing and murky skies have every legitimate reason to envy you. And warm comfortable air helps dark adaptation, or gives you the time to get fully adapted. It's nice, guys, and I admit it.

—Richard Berry

Letters

At the same time, it should be made clear that the optical errors of diagonal mirrors and other elements may or may not adversely affect the final image. That's why it is important to test every optical system *at the focus*, where the optical performance depends on all the errors in the optical path.

Mladen Vranjican
232 Carrie Drive
Franklin, VA 238519

Small Diagonals

Dear Richard/ In my recent article on the design and construction of my 17.5-inch Dobsonian (*TM#35*), I described the use of a small diagonal mirror to increase image contrast and reduce diffraction, cost and weight. There are two additional points that should be mentioned for those who choose to use small diagonals in their telescopes:

Collimation A telescope with a small diagonal can be tricky to collimate because you cannot always see the reflection of the edge of the primary mirror in the diagonal when the focuser is extended. Without being able to see the primary's edge, you cannot be sure your optics are centered on the optical axis.

I strongly recommend that telescopes with small diagonals be collimated using the methods described so well by D. Eric Allen in *Telescope Making #22*, page 4, and by Paul Valleli in the March 1988 issue of *Sky and Telescope*, page 259. The use of central spots on both the primary and secondary mirror scan make collimation quick and easy, and you don't have to be able to see the primary's edge to be sure everything is centered.

Just align the dots with the center of the focuser (or the cross hair if you use one) and it's done. At that point, a touch or two on the primary's collimation bolts to adjust the image of the focuser's eyehole should complete collimation.

Stray Light One of the good things about a large diagonal is its ability to block stray light coming from the side of the tube opposite the focuser. A smaller diagonal like the one I used is a less effective shield. With a smaller diagonal you can see past the edge of the diagonal, and thus external light can sometimes enter the field of view.

Telescope makers who plan to use small diagonals in a closed tube should take special care to be sure that the inside of the tube opposite the focuser is carefully darkened as described in your article "Inside the Well-Baffled Newtonian," in *Deep Sky* #25, page 28.

To obtain maximum contrast, telescopes with Serrurier trusses should be built with diagonal cage assemblies that completely shield the eyepiece from light coming from beyond the diagonal. This may mean: (1) making the truss a little shorter and the cage a little longer; (2) surrounding the truss with a fabric tube; or (3) observing from locations where there is absolutely no stray light (I wish!).

Telescopes with open "tubes" like the one described by Tom Burnes and Dick Suiter in *Telescope Making #19*, page 18, should always be equipped with a diagonal shield like the one they describe.

Clear skies and good seeing.

Ronald L. Ravneberg
GibsonFisher Ltd.
Management Counsels
550 East Town Street
Columbus, OH 43215

Not a Refractor

Dear Richard/ I have a bone to pick with the Rutten-Newtonian design described in *TM#35*. Undoubtedly this is a good design. All the numbers are there and a lot of TMs will be pleased. But even with the albeit smaller color error and a 20 percent obstruction ratio, there is one problem -- it isn't a refractor and it isn't ever going to be one. Have we all forgotten K.I.S.S.?

To give an alternative to the above design, one so obvious that I don't intend to write about it, I'll tell you a story. I built a 5-inch f/10 Newtonian to the highest optical standards. It has an optical window (these are fun) and a 3/4-inch diagonal for a 12 percent obstruction ratio. I gave it the best of every enhanced coating I could buy and get 95 percent throughput into my eye with non-multicoated eyepieces.

It obviously has no color errors, and it works like a dream. If I were tempted to compare it to a Christen, I wouldn't for the same reason I mentioned above -- this one isn't a refractor either!

Ed Turco
199 River Road
Lincoln, RI 02865

Margaret Heflin

Dear Richard/ Thank you for the coverage of our gathering (ALCON 88). We wanted to let you know, however, that Margaret Heflin died on the eve of the winter solstice, December 20, 1988.

You had mentioned her observing building in *TM#35* and showed her at her large binoculars. Margaret was seventy years of age and had been an active amateur in the Midstates Region and the Omaha Astronomical Club for sixteen years. She had worked at every function of the Omaha club that I can recall. She had and her husband held the office of Secretary of the Omaha club for the past twelve years.

Although Margaret had running battles with both cancer and heart disease, she always held her chin high and gave to all a smile and a word of encouragement. She and her husband Phil were regulars at conventions in the Midwest, so she was well known to hundreds of Astronomical League members in the area.

Margaret suffered from poor blood circulation in her legs and was able to pursue her observing by the use of electrically heated clothes. Nothing seemed to be able to keep her from her observing and her husband's side.

Margaret Heflin will be sorely missed by all who knew and loved her.

George E. Allen
3390 South 130th Street
Omaha, NE 68144

BENLEX® for Tubes?

Dear Mr. Berry/ I have seen scopes in *TM* that used aluminum, plexiglass, or some other material that is hard to fabricate in the home shop. Benlex® possesses high dimensional stability, is tough, resilient, and will not crack from impact or moisture.

We have used this material in place of many others and found it of superior quality. It is great for mirror cells, supports, and braces as such. I cut the parts for a heliostat out on a bandsaw, bored the bearing holes on my drill press, and installed bronze bearings by pressure fitting; this item works wonderfully. Even greater though is that Benlex® dampens vibration and is for all practical purposes nonresonant!

In March 1972, I put a 2.5-by-5-by-8-inch piece on a weather stand to evaluate the product. Seventeen years later it is still the same size (±1/32 inch) and unwarped, though its color has bleached a little. I have never had any reason to regret the use of this material in any commercial application such as the ones described above.

This item has cured a lot of headaches for me over the years. I hope others will find this versatile product useful. I recommend applying varnish or clear epoxy paint after fabrication.

Most plastic supply houses are more than happy to supply engineering samples so that their products may be evaluated. Hook on to a piece of this stuff and give it a few blows with a sledge hammer you will be surprised.

W.B. "Bill" McCaslin
The Observatory Trust
P.O. Box #1173
Cleveland, MS 38732

pH in Polishing

Dear Mr. Berry/ With your kind per-

mission, could I present an idea and invite comments from all the glass pushers and other interested parties in your readership?

Several recent articles (see refs. 1-3) suggest that when glass is in a water environment, as in polishing with water wetting the lap, some of the water actually diffuses or migrates into a very thin surface layer of the wet glass, forming a layer of hydration. Hydration makes the surface of the glass softer, and thus might increase the speed of polishing. Sounds strange, but here's more. It also appears that the acidity or pH of the water may be important. An acid environment reduces the softening, but an alkaline environment increases it.

Let me propose that by adjusting the alkalinity of the water used in polishing, we might be able to control the speed of the polishing process. If, when the water on the lap is more alkaline, the soft layer of hydration forms and renews itself more rapidly, and is deeper, this deeper layer of softer material might be expected to polish faster than the shallower, more brittle layer of hydration that results from acid conditions.

So far as I am aware, controlling the acidity or pH of the polishing environment has not been suggested in print by anyone before. Readers, do you know of any such references? The idea seemed bizarre to me at first. Surely, if pH were important, someone would have figured it out before now. But perhaps not!

If this notion were true, then certain peculiar aspects of the polishing process would suddenly make sense. Why, for example, was frequent cold pressing often recommended? The periods of pressing were far longer than required to ensure good contact with the lap. But if the long periods of wetness were deepening the layer of hydration, this would make the glass easier to polish, and the lap would appear to function more efficiently. Also, the misbehavior of certain pitch laps might be explained in terms of acidic impurities in the pitch. These acidic substances, leaching out into the polishing environment, would interfere with good hydration, and the glass would resist polishing.

So far as I am aware, no one has ever thought to test the pH of polishing pitch. The layer of hydration would also account for the continued wide use of water on the lap, in spite of evaporation problems. Fluids like glycols, which don't evaporate and cause temperature changes, might be preferred for polishing, except that glycols, being nonpolar solvents, probably don't generate the layer of hydration that seems to make water so useful in the polishing of glass. Also, when it seems that you have to refresh the rouge on the lap every five minutes to make the thing polish, it may not be the added rouge that's doing the trick, but the added water that is used to suspend the rouge. The added water could actually be rinsing acidic pitch-derived impurities off the lap, moving it more toward the alkaline side, and making it perform better for that reason.

If we wanted to test this idea by controlling the acidity or pH of the lap during polishing, how would we do it? The easiest way would be to use a chemical mixture called a buffer, which is designed to maintain pH at a level more alkaline that the neutral point of pure water, which in technical terms means setting the pH higher than 7.0.

Standard phosphate and borate buffers (Clark and Lubs mixtures) are easy to prepare (see below). We could set the pH at 8.0, 8.5, 9.0, or even higher if we wanted. There are at least two problems, however, that may occur if the pH goes too high (too alkaline). An excessively high pH might attack the metallic oxides (iron, cerium) used as polishing agents, reducing them from oxides to elemental metal. This would be undesirable. Also, certain glasses may be attacked by excessively alkaline conditions.

Some experiments may be in order. The worker could mix, for example, a one-hundred molar (0.01M) borate buffer with a pH of 8.5 and use this buffer along with abrasive as the polishing medium. Certain buffers can even be obtained, I believe, as a powdered mixture, something like a gelatin dessert.

How about it, my friends? What is the best pH for the different glasses we TMs need to polish? Is it really possible to drastically cut polishing times? Is there also a connection between pH and the quality of optical surfaces? I hope that at least a few readers will try the experiment and then tell the rest of us what happened. If this idea works, it could be important. And if it doesn't work -- well, at least we tried!

Herbert Highstone
P.O. Box 249
Monte Rio, CA 95462

1. Takata et al., "Effect of Water Content on Properties of Na2SiO2 Glasses." *Journal de Physique* Colloque C9, Supplement to Vol. 43(12), C 9-45, 1982.
2. Takata, Tomozawa, and Watson. "Effect of Water Content on Mechanical Properties of Na2O-SiO2 Glasses." *Journal of the American Ceramic Society* 65, 1982.
3. Oka, Wahl, and Tomozawa. "Effect of Surface Energy on the Mechanical Strength of a High-Silica Glass." *Journal of the American Ceramic Society* 64, 1981.

How to Mix Buffer Solutions Mixing your own buffer solutions is no more hazardous than mixing photographic chemicals. Treat all chemicals as poisons, of course, and keep children well away.

The pH of a buffer is set by mixing the proper amounts of two stock solutions, an alkaline solution and an acid solution. You can make the two stock solutions from lye and boric acid. Lye is either potassium hydroxide or sodium hydroxide; this is a supermarket type item. Boric acid can be bought at a drug store; my ten ounce container cost me $3.27 plus tax. We are not talking expensive chemicals here!

To make Clark and Lubs buffers for pH's ranging from 8.0 to 10.0, first obtain your chemicals, a scale weighing in grams, and a volumetric cylinder or beaker calibrated in cubic centimeters (cc). The stock solutions are 0.1N NaOH (sodium hydroxide) or 0.1N KOH (potassium hydroxide) for the alkaline solution, and 0.1M H3BO3 (boric acid) for the acid solution.

Make sure that the lye you have purchased is pure lye and not a drain cleaner containing added chips of aluminum (like Drano). Then weigh out either 4.0 grams of NaOH (preferred, if you can get it) or 5.6 grams of KOH, and dissolve the chemical in one liter (1000 cc) of water. The container in which the lye is sold will state whether the contents are postassium or sodium hydroxide; weigh out either 4.0 or 5.6 grams as appropriate. WARNING: Lye eats holes in skin and clothing.

Then bring another liter of water to a good boil. After pouring the boiling water into a Pyrex bowl, add 6.2 grams of boric acid, stir until completely dissolved, and allow to cool (the acid dissolves poorly in cold water). Now you have two stock solutions from which buffers of various pH's can be prepared.

The table below shows how to prepare 100 cc of buffer for the pH's indicated. Quantities can of course be multiplied, if required. If tightly stoppered in glass bottles, stock solutions and buffers should stay good for a month or two, but probably no longer. Plastic bottles admit gases and destroy solutions far more quickly.

Buffer Mixing Table

Alk Sol	Acid	Water	pH
4.0	50.0	46.0	8.0
10.0	50.0	40.0	8.5
21.0	50.0	29.0	9.0
34.5	50.0	15.5	9.5
44.0	50.0	6.0	10.0

The buffer with a pH of 10.0 is very nearly a 0.1M buffer, which is a rough way of saying that the buffer chemicals are present at a nearly one-tenth (0.1M) molar concentration. The buffer with pH of 8.0 is closer to 0.05M. These buffers probably could be used on the lap just as mixed. I suggested a 0.01M buffer elsewhere; the dilution of the buffer is one more area where experimentation is needed.

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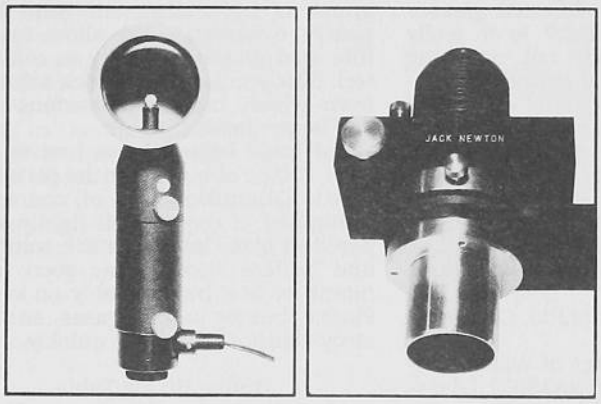

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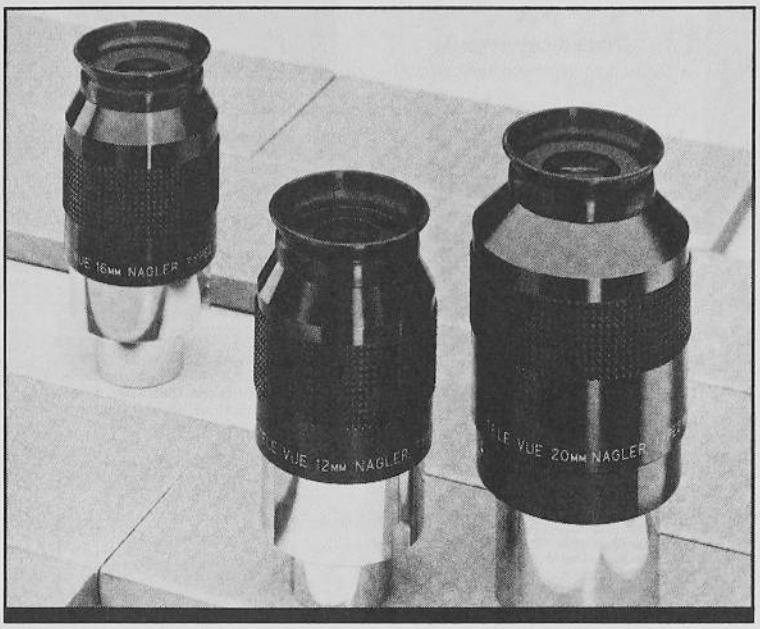

Design Goals

The basic Nagler series has already achieved image correction 10 times better than previous wide angle eyepieces (study in "Telescope Making" titled "The Nagler 13, a Remarkable Telescope Eyepiece"). We felt that extending the apparent field or image correction levels beyond that of the original Nagler series would *not* yield significant practical gains, but that extending the focal lengths *would* offer enormous potential for spectacular low power, wide-angle viewing.

In order to produce longer focal length Naglers, two practical limits had to be overcome:

1) Substantial physical size, weight, and cost increases would be impractical.
2) Scaling up exit-pupil aberrations would be unacceptable in our judgement. Although the 13mm Nagler eyepiece provides extremely sharp *images*, exit-pupil aberrations require a large (nighttime) eye pupil opening to encompass the full field. For this reason, daytime viewing with the 13mm Nagler is not recommended. Eye positioning is just too sensitive with the 7 element design to consider focal lengths longer than 13mm. The 9mm and shorter Naglers don't show this sensitivity.

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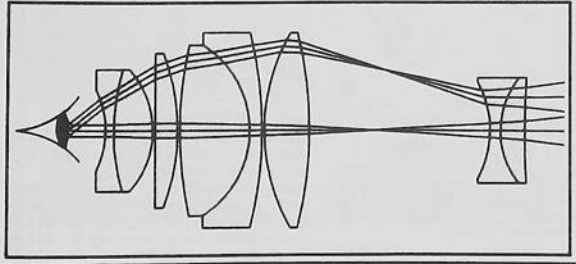

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16mm Nagler Type 2

Offers far more true field than the 13mm Nagler, yet is smaller and lighter. Great day or night performance with any telescope.

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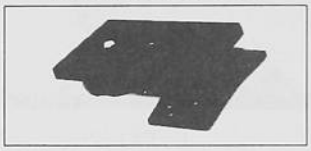

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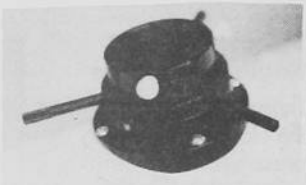

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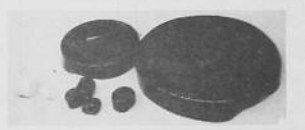

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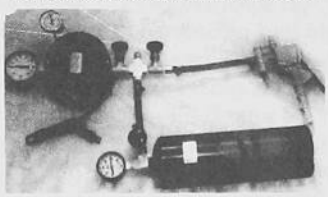

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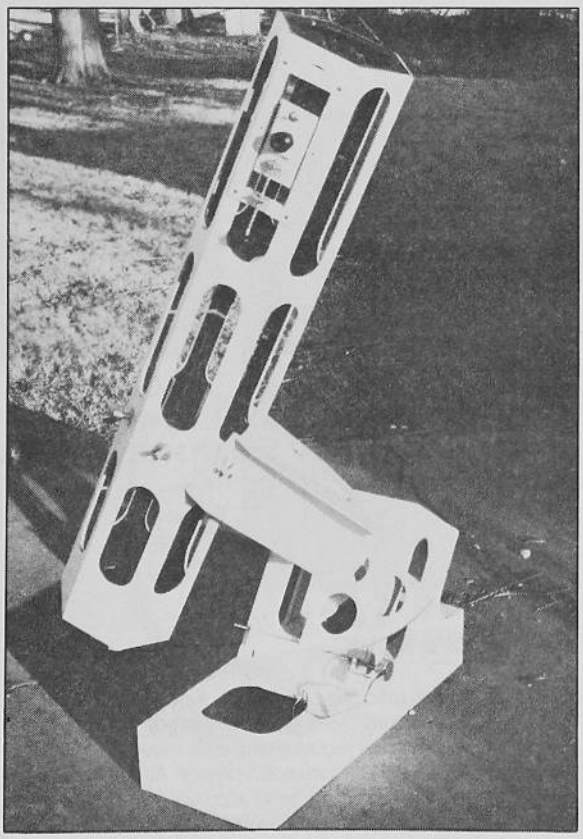

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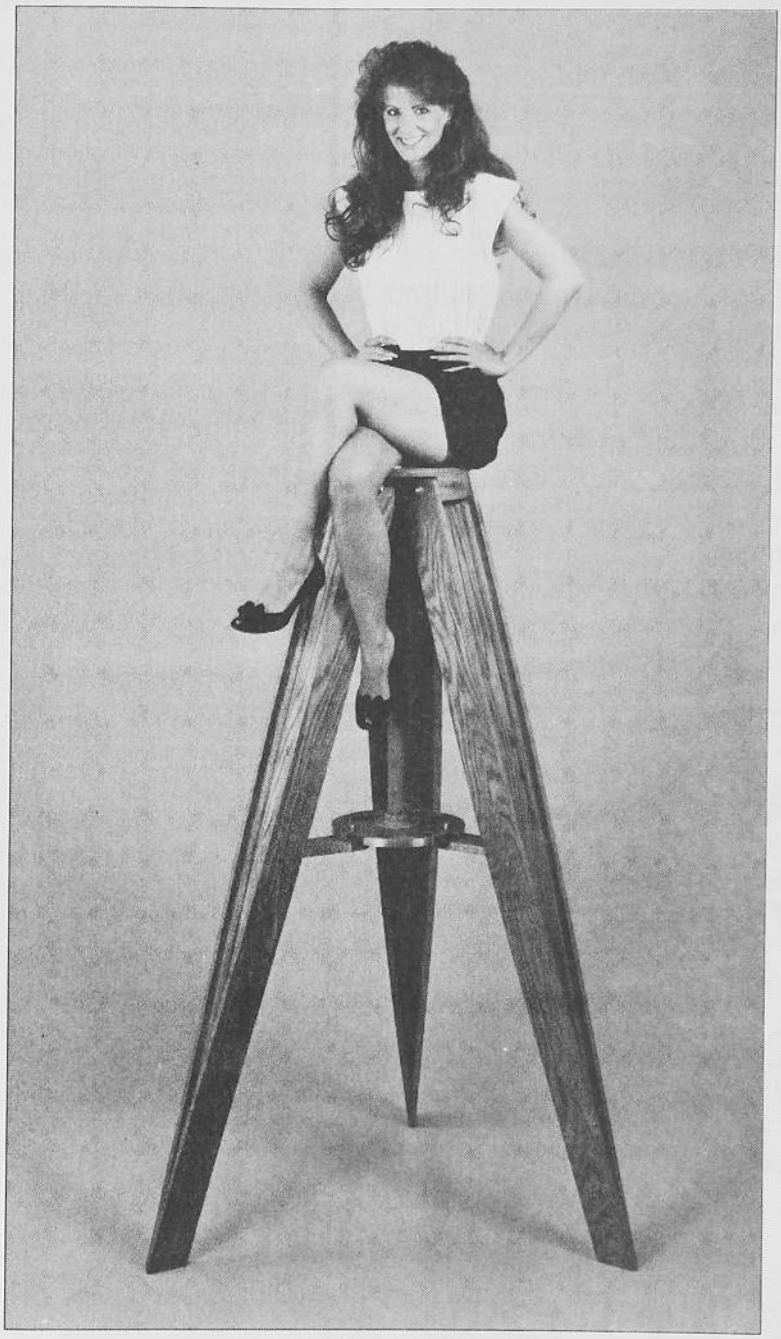

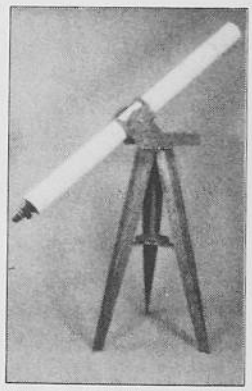

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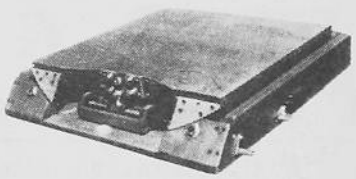

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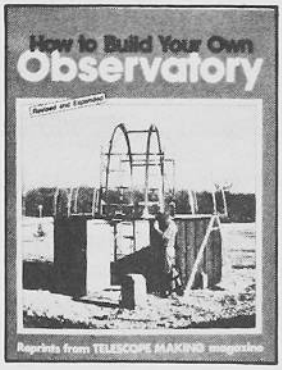

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9mm wireless illuminated eyepiece with movable reticle!

This 9mm Plössl is an astrophotographer's dream come true! Micro-adjusters allow you to move reticle within the field of view. Saves hours of work. Special double crosshair reticle also has two concentric rings. Red LED with brightness control. Diopter adjustment. 1-1/4" O.D. Multi-coated. **$129.95**

The exciting new Wide Scan™ offers the ultimate 80° viewing experience.

Now you can enjoy the 80° viewing experience without the excess size, weight, and expense usually found with this class ocular. And it didn't take us 9 lenses to accomplish it! Beautiful panoramic views, excellent pupil correction, and multi-coated optics for the brightest image of all. Special rubber eyeguards standard on all models. The 25mm model has a 70° field with 7 lens elements. 1-1/4" O.D.

10mm–$130.00, 13mm–$130.00, 20mm–$150.00, 25mm–$150.00

Pretoria™—is this perhaps the world's first professional telescope ocular?

The October 1988 product review in *Astronomy* states: "If you are looking for the perfect eyepiece for your fast Newtonian reflector, the Pretoria eyepiece is it." While the Pretoria does eliminate coma in fast Newtonians, it can dramatically improve the performance of any Newtonian. 25mm of eye relief in the 28mm model for those who must wear glasses. Multi-coated optics. For 2" or 1-1/4" holders.

28mm ..... **$225.00** **16mm** **$195.00**

The Klee.™ Not just another Barlow.

Designed by the master opticians who brought you the Pretoria, the 3X Klee is the first Barlow to fully correct its own astigmatism. No detectable on-axis image deterioration up to 7X! Unique 3 element air-spaced design. Fully multi-coated. **$75.00 0.5X and 1X Extension Tubes** are available at **$15.00 ea.**

Correct confusing views of the sky with our image erectors!

Tired of reversed images when trying to use your telescope and star atlas? We have two beautiful image erecting diagnols that can solve your problem. They also convert your telescope for terrestrial use. The 2" 45° Schmidt prism is multi-coated for maximum image brightness. The 1-1/4" model is of the Amici type and has a 90° viewing angle. A thumbscrew holds your eyepiece securely. Price for the **2" unit is $159.95.** The **1-1/4" Amici is $69.95.**

Deep-Sky Binoculars

These are the excellent quality 80mm binoculars we have been selling for years updated with full multi-coating and BAK-4 prisms. Available in 11 or 20 power, they come complete with case, tripod adapter, and collimation certificate. If you are considering binoculars in this class, please give us a call and get the true story. **11X or 20X–$275 ea.**

With the Gemini, astronomy with binoculars is no longer a pain in the neck!

This sturdy aluminum binoculars stand gives comfortable views of the night sky when using your favorite binoculars. You see more when your neck and arms are relaxed. Set it on a sturdy table or camera tripod and you are ready to enjoy the night sky! *Binoculars not included.* **$189.95**

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A full line of quality 2" and 1-1/4" diagonals to improve your viewing pleasure.

Our star performer is the giant full aperture 2" prismatic diagonal. It seals your primary optical system against dust and pollutants, and the prism surfaces will not deteriorate even after years of use. *We warranty this diagonal to outperform any diagonal made, regardless of cost, or your money refunded, no questions asked!* Price–**$179.00**

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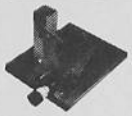

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University Optics now offers a full line of focusing mounts for every telescope maker's most exacting requirements.

Many telescope owners are surprised to discover that the new complex oculars now on the market can never realize their full potential if their field lenses are tilted off-axis due to sloppy focusing mounts. Our entire line of mounts are now made to yield absolute minimum lateral axial movement.

Vega-1, a rack and pinion focuser for 1-1/4" eyepieces.

Basic construction is aluminum with a chrome plated brass draw tube and helical rack and pinion. 4 tension adjustment screws. Racked-in height is 3". Provision for single vane holder. All hardware included–**$49.95**

The Vega-2 is the perfect match for those large Newtonians.

For years, the first choice of custom reflector builders, the Vega-2 offers a helical-cut rack and pinion, all metal construction, and large 1-1/2" focusing knobs. Takes 2" O.D. eyepieces and comes with a 1-1/4" adapter. Racked-in height is 3-3/4". All mounting hardware included–**$72.95**

The Vega-3 and Vega-5 are precision low-profile focusers.

These two new low-profile helical thread mounts stand only about 1-1/2" high. These are all aluminum construction and each unit has been hand fitted for an oil smooth thread fit. The 2" Vega-3 model is the perfect replacement unit for 1-1/4" devices found on some Dobsonian telescopes. The **2" Vega-3** is priced at **$50.00**. Add **$10.95** if you need a **1-1/4" adapter.** The smaller **1-1/4" Vega-5 is $36.95.**

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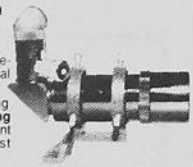

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